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CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Memoranda on Electric Lights. By J. K. WHILLDIN, Civ. Eng.

In the autumn of 1861, Prof. Way visited this country, and made several exhibitions of his electric light. The varieties of apparatus which he has employed, display much skill and ingenuity.

During the Professor's sojourn in Washington, the attention of the Lighthouse Board was directed to this light, and, through the instrumentality of Prof. Joseph Henry, and the energetic Secretary of the Board, Commander T. A. Jenkins, U. S. N., arrangements were made to exhibit it from Fort Washington, which can be seen from the Presidential mansion, and is distant in a direct line about 13 miles.

Accordingly, on Monday, Sept. 23, a small party, which the writer had the pleasure to accompany, left the Navy Yard in the steam-tug *Pusey*, and were landed at the Fort a little before sundown.

A Fresnel lens, of the 4th order, had been loaned for this occasion by Secretary Jenkins; it was placed on the parapet of the Fort, the apparatus adjusted to it, the battery filled, the mercury poured in the reservoirs, and in the course of a couple of hours everything was in readiness for a display of the light.

By previous agreement at Washington, certain signals, represented by numbers, were to be made to the President, who witnessed the light from the "White House." A rapid succession of flashes indicated when a signal was about to be made; then, if 23, for instance, was the number of such signal, there would be given, first, two dis-

tinct flashes; then a pause, say of half a minute, and again, three distinct flashes.

A large number thus made were sent during the evening, all of which were clearly seen and interpreted. The experiment continued about three hours, when our party returned to Washington.

Owing to the limited time for preparation, the arrangements in this instance were necessarily imperfect, and did not do justice to the skill of Prof. Way. It was not certain that the lens was quite level, or that the light was quite in the focus, and thus, owing to the small bulk of flame and consequent small divergence of the rays, it is probable that much light was either thrown above or below the horizon.

But, inasmuch as all essential features were embodied in the apparatus employed, it is hoped that a slight sketch may not be devoid of interest at a time when so much attention is being directed to superior modes of illumination.

The battery consisted of about 45 Bunsen elements (solid carbon as obtained from gas-retorts, and amalgamated cast zinc, nitric acid being the exciting agent). The cost of maintenance per hour is stated by Prof. Way to be about 38 cents; but this, he believes, may be reduced one-half by recovering the nitric acid and utilizing the product.

A noticeable objection to this form of battery is the abundance of nitrous fumes generated, which are very stifling, and would render indoor operations hazardous, if not impossible.

Prof. Way states that the magneto-electric machine, generating current electricity, will answer equally well for the mercury light.

It would, no doubt, in the majority of cases be substituted for a battery, although it would render necessary a steam engine or other power. Here is a case where a small economical motor, like Ericsson's hot air engine, might be advantageously introduced. One requiring no specially skilled labor, dispensing with such dangerous adjuncts as steam boilers, and independent of a water supply—not always to be had when most wanted.

Plate I., Fig. 1, is an elevation, partly in section, of the lens and apparatus as used at the Fort. Fig. 2 is an enlarged section of the parts immediately around the light. Fig. 3 is a plan of the lower part of Fig. 2, and shows how the flanch of the cylinder **C** is secured to the plate **K**. Fig. 1 is drawn about one-tenth of real size. Figs. 2 and 3 are quarter size.

The mercury is first poured into the upper cast iron reservoir **A** (Pl. I. Fig. 1), whence it issues through the wrought iron tube **E**, and is conducted immediately over the glass cylinder **C**, where the light is exhibited. The pipe **E** is connected with the parts below it by means of a short piece of gutta-percha tube; this arrangement permits the removal of the glass cylinder and attachments, the adjustment of the movable tube **D**, and also affords a convenient mode of stopping the flow of the mercury when desired.

The latter is effected by a steel clasp **L**, which compresses the tube tightly, but is removed when the light is in operation.

The sliding tube **D**, which enters the cylinder **C**, is made of steel, smoothly finished; it has a rack on one side, into which a small pinion gears, whereby the tube may be raised or lowered. At the lower end, there is an orifice not larger than a fine sewing needle; through this the mercury flows, in a stream resembling a thread of silver, into the small cup **H** beneath; said cup being of wrought iron, with its stem screwed into the cast iron plate **K**. The light is produced between the tube **D** and cup **H**, by the electricity traversing the slender thread of mercury, which it does when the wires **M** and **N** are connected with the battery to complete the circuit.

The cylinder enclosing the light is one piece of glass, both ends being cemented in brass flanches with red lead. The lower flanch and the plate **K** are carefully faced, so as to form an air-tight joint. All parts of the cylinder and attachments are made so as to completely prevent the escape of mercurial vapor into the outer air.

The mercury overflowing the cup **H**, passes into the lower cast iron reservoir **B**, by means of a wrought iron tube **F**, whence it may from time to time be drawn off, and returned to the upper reservoir **A**. The insulation of the reservoirs and attachments is effected simply by the wooden box shown in Pl. I, Fig. 1.

It is important to notice that, in the production of the light, the mercury is *not consumed*, but it may be used over and over again without any apparent deterioration or loss.

The *intensity* of the light varies with the battery power, it being a maximum some time after the battery is filled, and becoming weakened towards the close, as the acids become saturated.

The electricity dashes the mercury against the side of the cylinder **C**, and, after a time, patches resembling the coating of ordinary mirrors, adhere to the glass; these, being opaque, injure to some extent the efficiency of the light; but, as new cylinders can be readily exchanged for such as become coated, it is not believed that this is a serious difficulty. During the three hours the light was exhibited at Fort Washington, no deposit was found on the glass.

The capability that Prof. Way's light possesses, of being instantaneously lighted and extinguished, and in any order we please, renders it not only very valuable for military purposes in signalling, but also promises to solve an important problem in lighthouse engineering, viz: so to distinguish a given lighthouse from every other on a coast, as to enable the mariner approaching and seeing the light to determine his position, and thereby reduce the difficulty and avoid the dangers incurred in making a harbor.

By means of clock-work arranged by Prof. Way, the circuits are broken in any given order, producing corresponding occultations of the light; and a lighthouse may thus have a particular number given to it, indicative of its character and position; this number may be repeated at short intervals throughout the night.

The mode of distinguishing lights by occultation was proposed some years ago by Babbage, but not executed, owing, perhaps, to the difficulty of applying such a system to the present arrangement of opti-

cal apparatus. The flashing lights produced by the Fresnel lenses are the nearest approach to such a system that has yet obtained any considerable currency.

There is a great saving in bulk and cost of lens apparatus with the electric light. This will be the more apparent when we remember that our first order lenses, such as those at Capes May, Henlopen, Hatteras, &c., are about 6 feet diameter, and 9 feet high, and are obtained from Mons. Lepaute or Messrs. Sautter & Co., of Paris, at a price varying from $5000 to $11,000.

In the place of these, apparatus not exceeding in cost $400 or $500 might be readily substituted; indeed, Prof. Faraday states that all the light from an electric lamp might be utilized in a space not exceeding the size of an ordinary hat, reducing the cost yet more. It is well known that, with our present system, with oil lamps, we have but one method of increasing the *quantity* of light, that is, by increasing the number of burners, and thereby necessarily increasing the bulk of the flame; in a first order lamp, for instance, there are four concentric wicks, the outer one being about 3¾ inches diameter; this bulk of flame renders it exceeding difficult to utilize the light, for if the prisms are true for one point or focus, they will not be so for other points in the luminous mass, and it becomes necessary that the lens be large in order that the flame may be relatively small.

But with the electric lamp, any amount of light may be accumulated *in the focus*, by increasing the amount of electricity, which, of course, involves a corresponding increase in cost.

Prof. Holmes' magneto-electric light, with carbon points, has been on trial for six months in the South Foreland lighthouse, England, and, from the evidence given in a late Parliamentary report (1861), it would seem to have been eminently successful.

In France, also, a somewhat similar arrangement has been successfully employed, the magneto-electric machine being slightly different, the currents in the English machine being in one direction, while those in the French machine alternate. No practical difference between the two lights has been detected.

Prof. Faraday compared the intensity of the electric light with that of the sun, by means of dark glass; they were about equal, but the sun was not at its brightest. In relation to the South Foreland light, he says:—"The eyes of the keepers are not affected, though the blue glasses provided for them are very pale in color, for the light is better watched by observing the *place* and *intensity* of the rays which fall here and there on the walls of the lantern, than by looking at the light itself."

In France, experiments made by Mons. Reynaud and others, show the comparative intensities of various lights, as follows:—

Argand burner,	1.
First order flash,	80 to 90.
Electric light,	94.
" cast glass flash,	55,000.
" first order flash,	220,000.

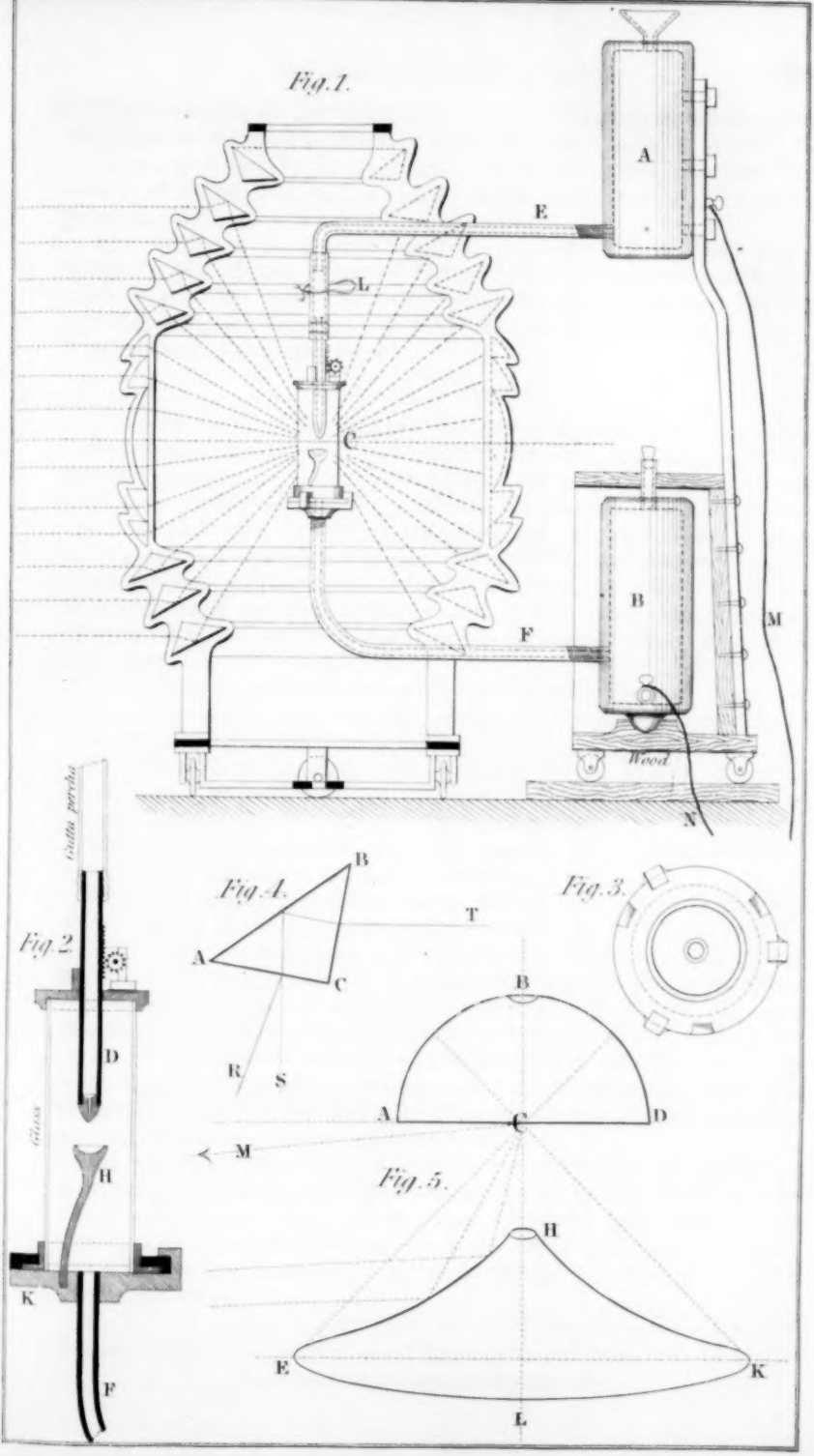


Fig. 1.
A
E
L
C
B
F
M
Wood
N
Gutta percha
Fig. 2
D
Glass
H
K
F
Fig. 4.
B
T
A
C
R
S
Fig. 3.
B
A
C
D
M
Fig. 5.
H
E
K
L

The intensities of the lights were tested by looking at the shadows projected by them on a screen of whitened glass, placed at a distance of 20 yards from the electric light; the figures given above are the results of calculation, and cannot be taken as exact, though they express the differences roughly.*

The ability of the electric light to penetrate a thick, hazy atmosphere, will doubtless be one of the strongest inducements for its introduction. The sailors on board steamers plying between France and England, say they can see Prof. Holmes' light, in such weather, 7 miles further than any other.

UTILIZATION OF THE LIGHT.

The superiority of the dioptric lens over reflectors has been generally insisted upon; but Prof. Potter, of London, who has made extensive photometric experiments, doubts the great advantages which have been claimed for the Fresnel lens. He has found that about one-fourth of the light is lost by reflection and absorption in passing through a thickness of *two inches* of clear flint glass with highly-polished surfaces, and that good, ordinary looking-glass reflects *six-tenths* to *two-thirds* of the light falling upon it, and that highly-polished mirrors, of speculum metal, as used in reflecting telescopes, reflect still more.

Prof. Faraday states the absorption of light by dioptric apparatus to be 50 per cent., and that pure silver, highly polished, reflects 95 per cent. of the total quantity falling upon it.

Sir David Brewster considers a spherical mirror composed of flint glass prisms, as used in the many forms of holophotal apparatus, as greatly inferior to one made by Foucault's process.

Sir J. F. W. Herschel has recently proposed an improved reflector, which is likely to prove a great economizer of light.

With the ordinary parabolic form, part of the light is thrown upward against the sky, unnecessarily illuminating the stars; and although, in the Fresnel lens, this defect is remedied to some extent, there is still considerable loss, more especially in the catadioptric zones. This will be readily seen by referring to Pl. I., Fig. 4, where **R**, the ray proceeding from the focus, is refracted to the back of the prism **A B C**, and then reflected and refracted out towards **T**, whereby much light is absorbed in pursuing such a circuitous route; and when the zones or prisms are highly polished, as they usually are, there is also the additional loss by reflection towards **S**.

The loss from imperfect brilliancy of the ordinary plated reflectors is greatly reduced by the recent discovery of Liebig, wherein pure silver is precipitated from its solution, contained in a thin shell of glass. The silver, by this method, is protected against all the agencies which tarnish it, and it is affirmed that 91 per cent. of the light is reflected by it.

Sir J. F. W. Herschel proposes to make use of these mirrors, at the same time so arranging their shape that the losses and disadvan-

* See Report of English Lighthouse Commission, 1861.

tages due to the common form may be avoided. This is accomplished as shown in Pl. I., Fig. 5, **C** being the focal point, or source of light, **ADB** being a hollow hemispherical reflector, **EHK** a conoidal reflector, whose surface is generated by the revolution about the vertical axis, **CL**, of an ellipse whose major axis, **CM**, dips below the geometric horizon. By the above arrangement, it has been demonstrated that the most advantageous dispersion of light over the sea surface is obtained, while the entire horizon may be illuminated, if necessary, by a single flame, as in the dioptric arrangement. All the light diverging upward is turned back, and, passing again through **C**, radiates thence downward, and in effect nearly doubles the intensity.

Although adapted to ordinary oil flames, the most appropriate light is considered to be that obtained by electricity.

The Earl of Rosse in commenting upon the present defective mode of constructing reflectors of thin sheet metal, says reflectors should be cast of gun-metal (9 of copper and 1 of tin), turned in a lathe to obtain a true surface, electro-plated carefully, and finally polished in a lathe.

WASHINGTON, D.C., March, 1862.

The Shearing Strains of Deflected Girders. By HOMERSHAM COX, M.A.

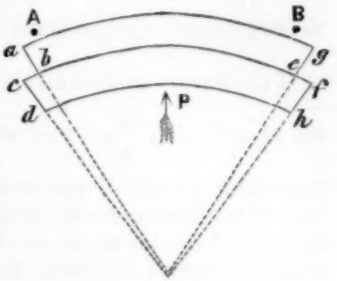
From the Civ. Eng. and Arch. Jour., Aug., 1861.

Of late years, the shearing strains of deflected girders, that is, the strains which result from the tendency of the particles of the beam to slide on the surface of each other, have received much attention. The object of this note is not to add anything to the mathematical theory of the subject, but to point out a simple case in which, with little aid from mathematics, the important effects of the tangential or shearing strength of beams are strikingly shown.

The ordinary theory of beams does not take into account the tangential displacement of particles, but supposes that those particles which are opposite to each other before deflection remain opposite after deflection, and that the only displacements are normal compressions and extensions. This assumption, though not absolutely correct, is sufficiently so where the transverse dimensions of the deflected beam are small compared with its length. In such cases, the tangential elastic forces of the material are generally sufficient to prevent any considerable tangential displacement. But the effect of those forces may be readily seen by the effect on the statical strength of a beam which would result from removing, artificially, part of them.

Suppose a horizontal straight beam, of which the section is rectangular, to be actually divided into two equal parts by a smooth section parallel to its upper surface; and suppose then the two parts of the beam remaining in contact to be deflected as in the diagram by a force or forces perpendicular to the surface of the beam, so that the deflections are equal at equal distances from the fulcra A and B. The diagram represents a section of the beam in the plane of deflection. The deflecting forces act on the concave surface of the beam. The section

$a\,b$ of one end of one part of the beam will not after deflection be in the same straight line with $c\,d$, the section of the end of the other part, as would be the case if there were no shearing strains; but $b\,e$ in the concave surface of the part of the divided beam next A B will be shorter than $c\,f$ in the convex surface of the other part of the beam.



This may be seen very readily in the case where the deflecting pressures are such that the curves shown in the diagram are circular arcs. The neutral line of $a\,b\,e\,g$ and that of $c\,d\,h\,f$ are both equal in length, for they are both equal to the length of the beam before deflection. But the former neutral line is the arc of a circle of a radius larger than the radius of the circle of which the latter neutral line is an arc; and therefore, since the two arcs are equal in length, but have unequal radii, the former subtends a smaller angle than the latter.

In order to estimate the loss of the strength of the beam consequent on the division along $b\,e$, suppose only a single deflecting pressure P to act perpendicularly to the line joining A and B, the two points of support, and midway between them. Let x be the distance from B measured parallel to the straight line A B of any point in the neutral line of the beam $a\,b\,e\,g$; and let R be the radius of curvature of the neutral line at that point; E the modulus of elasticity of the material; I the moment of inertia of the rectangular section of the beam $a\,b\,e\,g$ about an axis through its centre of gravity perpendicular to the plane of deflection. By the ordinary theory $\frac{E\,I}{R}$ is equal to the moment about the same axis of all the forces acting upon the part of the beam between the point in question and the nearest end of the beam. These forces are, the pressure of one of the abutments, and the pressures of the intervening part of the surface of the other beam $c\,d\,h\,f$. Let M represent the moment of the latter, and $\frac{1}{2}\,P\,x$ the moment of the pressure of the abutment.

Then, $\frac{E\,I}{R} = \frac{1}{2}\,P\,x - M$. For the beam $c\,d\,h\,f$, taking moments about an axis through that point of its neutral line which lies in the radius R, we have $\frac{E\,I}{R'} = M$, where M is the same moment as before, only affected by the positive sign, and R′ is the radius of curvature of the neutral line $c\,d\,h\,f$. Now owing to the contact of the two beams, and their being subject to no compression in the directions of the normals to their surfaces, it may easily be seen that at the points of which R and R′ are the radii, the neutral lines have a common centre of cur-

vature, and that consequently R and R′ differ in length only by the part of R between the two neutral lines. This difference is inconsiderable compared with R. We therefore have approximately (adding the two preceding equations) $\frac{2EI}{R} = \frac{1}{2}Px$.

If the beam were not divided into two parts in the manner supposed, we should have $\frac{Ei}{r} = \frac{1}{2}Px$; where i is the moment of inertia of the transverse section of the undivided beam, and r the radius of curvature at the distance x from B. Now the section being rectangular, the moment of inertia varies as the cube of the distance between the convex and concave surfaces. This distance is twice as great for i as for I; consequently $i = 8I$. Therefore $\frac{1}{r} = \frac{4}{R}$. It follows that the deflection produced by P will be four times as great when the beam is undivided as when the beam is divided. Assuming the ultimate strength of a beam to be proportional to the moment of inertia of its transverse section, it follows also that the breaking weight at the centre of the undivided beam is four times that at the centre of the divided beam. In other words, *the effect of dividing the beam in the manner mentioned, is to reduce its strength and rigidity to one-fourth of its original strength and rigidity.*

On Measuring Distances by the Telescope. By Mr. W. B. Bray, M. Institution C. E.

From Newton's London Journal, Jan., 1862.

The author's attention was attracted to this subject by a paper, by Mr. Bowman, read before the British Association in 1841; but it required further investigation and modification, to bring it into a form of practical utility.

He found that it was convenient to have two distinct hairs on the diaphragm of the level—one about $\frac{3}{20}$th of an inch above the level hair, and the other as much below, so as to read 1 foot on the staff at 1 chain, and 10 feet at 10 chains. Since, however, in focusing the instrument to any object, it was necessary to bring the cross hairs into such new focus, which was proportionally further from the object glass as the object was nearer, the angle which the hairs subtended from the centre of the object glass must be variable, diminishing as the distance was diminished. Hence a correction was necessary, and this the theory of refraction by lenses furnished. It showed that the error was constant at all distances, amounting in every case to the focal length of the object glass for parallel rays. This constant was to be added in reading the staff, by bringing the lower cross hair near any even division of feet, but exactly ·02 of a foot above it, corresponding with the two links from the centre of the instrument to the anterior focus, in

the cases of a 5-inch theodolite and 10-inch level. Then, by reading the upper distance hair, and deducting the even number of feet at the lower hair, the difference was the distance in chains and links. If the compass was sufficiently delicate, any operation of contouring, or running trial levels, could be performed with rapidity and accuracy.—When provided with the two distance hairs, the level of the ground could be taken above and below the ordinary range of the instrument. The use of these distance hairs for eighteen years had proved their practical value. In taking the widths of rivers or deep ravines, distances of 20 chains had been read in favorable weather; and when the hairs were accurately fixed on the diaphragm, they might be used for even fractions of a link, in taking widths incapable of direct measurement.

When applied to a theodolite, they could be used for measuring distances on sloping ground. But in that case, since the line of sight was no longer perpendicular to the staff, a correction was necessary, for which a table was given, showing the angles of elevation of the various heights, which were simple fractional parts of the horizontal distance. When the horizontal distance to the staff had been ascertained, the theodolite was to be elevated to the tabular angle corresponding to the fractional rise nearest to the slope of the ground; then that fraction of the horizontal distance, less the reading of the staff, would be the correct rise. With the theodolite, it was convenient to have another set of hairs, for reading the distance in feet, as well as in links. In clear weather, with a distinct reading staff, a distance of 40 chains had been read between the foot and link hairs.

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In the course of the discussion it was remarked, that the arrangement described by the author, was of much earlier date than had been mentioned. Possibly its application might hitherto have been limited, from the want of a correction for the errors introduced in focusing the instrument, which had now been supplied. Reference was made to the micrometer arrangement of the diaphragm in Mr. Gravatt's original dumpy level. This system of measuring distances had lately been applied to rifle practice, and for military purposes generally; and it was thought that a micrometer telescope could be relied on for distances, up to 12 or 15 miles. It had also been employed for determining the speed of vessels at sea, when the exact length of the vessel was known, as well as for other purposes.

It was observed that the great improver of instruments of this kind was M. Porro, an officer of Engineers in the service of Piedmont, a detailed account of whose "*Instruments pour les lèves de plans*," was given by M. H. de Senarmont in the *Annales des Mines*, 4th Series, vol. xvi, (1849.) None of the modifications in M. Porro's instruments had been introduced into this country, and yet with his micrometer scale of wires, the staff could be read off in metres at once—and it was stated, at a distance of 800 metres, the error did not exceed two centimetres.

Proc. Inst. of Civil Engineers, Nov. 19th, 1861.

For the Journal of the Franklin Institute.

On the Practical Limits to Economy from the Expansive use of Steam.

The laws which govern the action of steam in the production of power, indicate a large economy from its use when allowed to expand after communication with the boiler has been closed. Experience has, within certain limits, seemed to verify this indication, and the economy due to expansion has become almost a dogma in engineering

Within a very few years, some have been found bold enough to question the value of this generally received opinion, and have instituted experiments for the purpose of demonstrating its truth or falsity. It is not easy to make *reliable* experiments on this subject, upon such a scale as would in practice entitle their results to credit.

It *is* easy to try experiments apparently conducted with care on any given engine, observing the effect of different rates of expansion, which, however correctly observed or noted, are utterly valueless in determining the true point at issue. For from the nature of the case, they having been tried on the *same* engine, with the *same* load, the conditions of a true comparison have not been fulfilled; viz: that the conditions be the same. It is evident that in such a case, varying the rate of expansion, involves for the maintenance of uniform power, (*mean* pressure) a change of initial pressure. A mean pressure for example, of 20 pounds, requires, when working at full stroke, 20 pounds initial pressure; when cutting off at one-third stroke it requires 28½ pounds, or more than forty-two per cent. more, &c.

Consequently it is seen, that in the case described, which is almost the only kind ever tried having this object, *two* changes are made, first, a change in the rate of expansion; secondly, a change in boiler or initial pressure. Nor can the difficulty be overcome by throttling. There is a certain loss from condensation when steam is expanded, whether the expansion takes place at the throttle or the cut-off valve. If, then, steam be generated of the pressure required for the high rate of expansion, it ought to be *used* at that pressure with the low rate of expansion. It needs no argument to show that this is simply impossible when the same engine is used to drive the same load.

Apart from the varying degree of economy with which steam of different pressures can be generated, a change of maximum boiler pressure affects the loss by radiation and leakage, and, more important still, the question of cost, size, and weight of the machinery required. If a boiler is to be constructed for a working pressure of twenty pounds per square inch, if an engine is to be designed for such pressure, the cost and weight of both will be less than if thirty pounds is to be the limit.

Now these conditions of size, cost, and weight, are precisely those most important in a practical point of view, next to economy, but are apt to be left out of the question by the theorist.

The true practical question at issue is simply this: *Given*, a standard maximum steam pressure, and a standard maximum resistance, at what rate of expansion shall the steam be used to produce the best and most economical results, all things considered?

By "all things" I mean principally, economy of first cost, of wear and tear, of fuel, space and weight. Stated in more concise terms it stands thus: Are large or small cylinders best for the development of power economically?

The solution of the question depends on considerations partly theoretical, partly practical; while they may be enumerated in terms sufficiently concise, their value and true bearing can be ascertained only by properly conducted experiments.

Some of the causes which may operate in favor of using smaller cylinders, or a lower rate of expansion, are as follows:

1. The condensation of steam due to, and inseparable from, its expansion when communication is cut off from the water from which it has been generated; the amount of loss from which is greater, the further the expansion is carried.

2. The heat taken from the steam to evaporate, at continually reduced pressure consequent on expansion, the water previously condensed from it; the amount of which loss increases as the rate of expansion is raised.

3. The loss of heat from radiation, externally and internally from the surfaces of the cylinder and heads; it being greater as the size of cylinder is increased.

4. The amount of steam lost in filling the ports and clearances of the cylinder, which, although producing a small dynamic effect, increasing with the rate of expansion, is, nevertheless, a positive loss, greater in ratio of the size of cylinder.

5. The tension of vapor on the exhaust side of the piston, or back pressure, a constant resistance for any rate of expansion, necessarily increases in amount, the greater the size of cylinder.

6. The pressure required to overcome the resistance of the engine alone, doing no work, simply overcoming the friction, working the pumps, &c., and maintaining the velocity; which is ordinarily from $1\frac{1}{2}$ to $2\frac{1}{2}$ pounds per square inch in a well proportioned engine, and is of course, in proportion to its size, or that of its cylinder.

7. Cost, space, and weight, increase in proportion to size of cylinder, as also does the expense of wear, of oil, of renewal, &c.

In favor of the larger cylinder, rendered necessary to obtain the supposed benefit from expansion, it has been urged that the surplus pressure exerted before steam is cut off, acts beneficially in overcoming the inertia of the moving parts of the engine. This argument appears to me fallacious. In a well designed engine (intended to rotate a shaft for giving off its power) the reciprocating parts should combine as *little weight* as possible with the requisite strength and rigidity; by which the inertia and momentum are reduced to a minimum, and are overcome by that of the mass in rotation. Such an engine, when at work, is supposed to be moving at uniform speed. Its revolving parts have therefore no inertia to overcome due to change in direction of motion, and that of the reciprocating parts at each change of direction, if properly designed, is comparatively so little,

that it does not affect the speed perceptibly. So far from being a benefit, a surplus pressure at the beginning of each stroke, and a deficient pressure at the end of it, are positively injurious, and will infallibly tell upon the working of the engine, and in its bills for repairs if carried to an extreme.

With engines which do not communicate their power through a shaft, but which, like the Cornish engine, either operate directly on the resistance, or upon a mass which in its turn overcomes the resistance, in either case starting each stroke from a state of rest; the whole aspect of the case is changed. Here an excessive impulse is required in starting the load, to overcome suddenly its inertia. The great power thus stored up is not expended until long after steam is shut off, and indeed long after it has ceased to impel the mass; which finally when its momentum is expended, stops. In this case a large cylinder is necessary; and as a consequence, a high rate of expansion. But the great economy of this class of engines is mostly due, not to expansive working, but to the peculiar application of the power. At least, because a large cylinder and high expansion may apparently produce benefit in this case, we have no right to anticipate equally good results from the same things applied under different practical conditions.

It has been before stated that the value or effect of the various causes, tending to modify the theoretical gain from expansive working, could be determined only by properly conducted experiments; and that the experiments generally tried with this object in view were not so conducted.

To fill this want of the profession, a Board of Naval Engineers of the United States, made by authority in November, 1860, on the steamer *Michigan*, a series of experiments, which, for care and elaboration are not surpassed, if equalled, by any others recorded of a similar nature.

The conclusions of the Board, and their method of conducting the experiments, have been the subject of controversy in this Journal. It is not my purpose to enter into a discussion upon, or to defend, the course pursued by the Board. Each reader of their report who approaches it with an impartial spirit and a desire to attain a true understanding of so important a subject, will probably form his own conclusions.

After a very careful study of it, I am satisfied that some misconceptions exist on the subject, and that, rightly construed, their suggestions are entitled to grave consideration.

The method adopted in making their investigation was to vary the load in such a manner as to maintain with the same boiler pressure, the same *mean* pressure with different rates of expansion. This proceeding was equivalent to varying the size of cylinder, the boiler pressure and load remaining the same.

The method adopted in comparing results, was to adopt as a standard of power developed, the amount of water pumped into the boilers: thus eliminating every thing appertaining to quality of coal, methods

of firing, relative amount of boiler and grate surface, &c., the weak point in comparisons where great accuracy is required.

It does not appear that in any respect, the care and attention requisite in such researches, were wanting. The tank was placed in such a position as to prevent the possibility of unknown leakage; and each trial extended uninterruptedly over 72 hours. The machinery was of size sufficient to make the results valuable practically, and it is probable, was in better condition generally, than marine machinery ordinarily is when in service.

The boiler pressure was kept throughout the trials at 20 pounds above the atmosphere, or 34·7 pounds total. The "back" or condenser pressure averaged 2·7 pounds (an unusually low figure, it being generally at least one pound higher—the difference being in favor of high expansion).

Without taking into account the power consumed in engine resistance, the following results were obtained:—

Points of cut-off,	1 1/2	7/10	4/9	3/10	1/4	1/6	4/15
Economic result,	1·000	0·889	0·859	0·912	0·906	0·967	1·088

It is apparent that an increase of boiler pressure would modify this comparison, because the back pressure remains the same, while the mean pressure is decreased with increasing rates of expansion; consequently acting more injuriously on the nett power at higher rates. To show, however, that modification from this cause is not great, the following table gives the comparison of different rates of expansion, without allowing for any back pressure:—

Point of cut-off,	1 1/2	7/10	4/9	3/10	1/4	1/6	4/15
Economic result,	1·000	0·882	0 840	0·874	0·852	0 877	0·915

When the effect of engine resistance equal to 1·7 pounds per square inch, as well as back pressure, is taken into account, the results are as follows:—

Point of cut-off,	1 1/2	7/10	4/9	3/10	1/4	1/6	4/15
Economic result,	1·000	0·896	0·877	0·949	0·962	1·065	1·292

This table contains the *substance* of the whole set of trials. For as no engine can work without back pressure and its own resistance, it is the nett power, after deducting these two resistances, which must be compared. The amount (ascertained by experiment) for the latter of these elements is low, and shows the engine to have been in good condition; it generally varies in well designed engines from 1·5 to 2·5 pounds.

It thus appears that the most economical point of cut off is 1/2, then 7/10, 2/3, 1/4, 1 1/2, 1/6, 4/15.

Those who find it difficult to accord these apparently extraordinary results with what they have observed in practice, overlook the fact that their observations have been made on the *same* engine, whereby they have ignored the modifying effect which would have resulted

from the employment of a properly proportioned cylinder; *i. e.* a cylinder of such size as would preserve the mean pressure the same.

The following table gives these proportions:—

Point of cut-off,	$\frac{9}{10}$	$\frac{8}{10}$	$\frac{7}{10}$	$\frac{6}{10}$	$\frac{5}{10}$	$\frac{4}{10}$	$\frac{3}{10}$	$\frac{2}{10}$	$\frac{1}{8}$	$\frac{1}{8}$
Size of cylinder,	1·000	1·010	1·032	1·115	1·207	1·359	1·615	2·160	2·494	3·181

It is calculated for an initial pressure 30 pounds above the atmosphere, 3 pounds back pressure, 2·1 pounds engine resistance.

To show that this change does produce an important effect on economic results, the following calculations are here introduced:—

Suppose an engine of 60 ins. diameter of cylinder, 3 feet stroke, with clearance space equalling 3 ins. of stroke, in which steam of 30 pounds (above atmosphere) is cut off at 3-10 stroke, back and engine resistance as above.

Steam consumed each half revolution.

3 ft. × 3-10 = 0·90 ft. + 0·25 clearance = 1·15 feet.
Area 2827 sq. in. = 19·63 sq. ft. × 1·15 = 22·574 cub. ft. of a density 613·6 gives ·03679 cub. ft. water used.

Power developed.

2827 × 44·7 total press.	×	·662 coeff.	= 83650·93
Less back pressure,		3·0	
And engine resistance,		2·1	
2827	×	5·1	= 14417 70
Nett pressure,			69233·23 lbs.

And 69233·23 × 3 feet stroke = 207699·69 ft. lbs. exerted each half revol.

If now the same cylinder be used cutting off at 7-10, the steam consumed will be—

3 ft. × 7-10 = 2·10 + 0·25 = 2·35 × 19·63 = 46·130 cub. ft.

Power developed will be—

Back and engine resistance as before,	14417·70
Nett pressure,	69233·23
Gross "	83650·93 ÷ 2827 = 29·59 pounds.

Coeff. of 7-10 = ·951, therefore $\frac{29·59}{·951}$ = 31·11 initial pressure,

of which density is 854·5.

Hence the Water used will be $\frac{46·130}{854·5}$ = ·05397 cub. ft.

Comparing these two results from the same cylinder,

Cutting off at 3-10 steam consumed 0·3679 or 1·000
" " 7-10 " " ·05397 to 1·467

the same nett power being produced.

But suppose the cylinder diminished so that the same pressure may be maintained equal 30 pounds until cut off at 7-10 stroke.

Power (nett) as before, = 69233·23 obtained with
steam, initial pressure, $\left\{\begin{matrix}30·00\\44·70\text{ total}\end{matrix}\right\}$ cut off at 7-10, coeff. = ·951 = 42·51
Less back pressure and engine resistance = 5·10
Nett pressure throughout stroke, in pounds per square inch, 37·41

Area of cylinder = $\frac{69233·23}{37·41}$ = 1850 sq. ins. = 48½ ins. dia.

Steam consumed.

3 ft. × 7-10 = 2·10 + 0·25 = 2·35.

Area 1850 sq. ins. = 12·84 × 2·35 = 30·174 cub. ft., of a density = 613·6 or ·04917 cub. ft. of water.

Comparing this result with that from the larger cylinder, we see that the ratio between 3-10 cut off there and 7-10 here is

With large cylinder cutting off at 3·10 ·03679 or 1·000

to

With small " " " " 7-10 ·04917 1·336

The advantage of using the proper size of cylinder in this case, to obtain the same power, is as

1·467 to 1·336, the difference, on the unit of power with high expansion, being over 13 per cent.!

This it will be remembered is purely the result of loss by clearance, back pressure, and engine resistance. To reconcile the theoretical economy still existing, with the observed results, we must refer to the other sources of loss referred to earlier in this paper. When it is remembered that the internal and external surface is one-third greater, that the terminal pressure is less than one-half, that the terminal temperature is reduced from 233° to 196°, that expansion (involving condensation) is carried to double the extent, on three-fourths the weight of steam, or to one-half greater extent on the same weight, in the larger cylinder, it will be less difficult to reconcile the theory and the results.

Add to these considerations, that we have an engine to build and preserve in good condition, which will not cost over 80 per cent. that of the larger one, of a simpler character, of less weight, and occupying less space, and we are more disposed to accept the results than the theory.

At all events, if these arguments possess any weight, it would seem that the suggestion made by the Board as a result of the Erie Experiments, to wit, that for general purposes rotating engines should be designed for a maximum resistance requiring steam to be cut off at $\frac{7}{10}$ stroke, is practically a tenable position. The link motion, or some simple valve gear, would enable this cut-off to be shortened to $\frac{1}{2}$ stroke, with an economy nearly the same as if that had been the normal point of cut-off intended.

The advantages to be derived from complicated mechanism for expansion gear, to obtain "sharp corners" on the cards, and for varying the cut-off from nothing up to full stroke, are rendered by such an argument exceedingly mythical.

Not that they may not produce benefit when applied to any given engine already in use for doing a certain work, which has been designed too large for that work; but that *better* results might be obtained by proper proportions in engines designed on the basis indicated.

It is from the foregoing evident, that the labors of the Erie Board cannot greatly modify existing practice; but I am disposed to think they will in time modify existing ideas, which will hereafter produce their proper fruit. J. V. M.

PHILADELPHIA, March, 1862.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Analysis of the Gamut in the Major and Minor Modes.

By C. J. W., Jr., Germantown, Pa.

(Continued from page 182.)

By examination of the table of modulations above, it will be observed that we have, by successive steps, gradually approached the key of Do natural with which we set out; and that we have finally reached it, by the introduction of twelve flats into the signature. The keynote of twelve flats is actually the note Re double flat, and Re double flat is practically the same note as Do natural. We have thus in three different ways produced the keynote of Do natural, or its equivalent; first, by dispensing totally with the use of flats and sharps; next, by the introduction of twelve sharps into the signature; and lastly, by the introduction of twelve flats into the signature. It will now be shown that this is by no means a solitary instance of the existence of identical keys, but on the contrary, that each key represented by sharps has its counterpart, though under a different title, to be found represented by flats.

For instance: by reference to the table of consecutive sharps, it will be seen that the key of four sharps is the key of Mi or E natural. But Mi natural is equivalent to the note Fa flat, and by reference to the table of successive flats, it will be found that the key of Fa flat is the key of eight flats.

The keys therefore of four sharps and eight flats are identical.

Again: by reference to the same tables, it will be seen that the keynote of two sharps is Re or D natural; but the note Re natural is identical with the note Mi double flat, and Mi double flat is the keynote of ten flats. The key of two sharps, therefore, is identical with the key of ten flats.

In the same manner it may be shown that the keys of three sharps and nine flats are identical; that the keys of five sharps and seven flats are identical; and generally, that the key represented by any number of sharps, is identical with the key represented by that number of flats which added to the number of sharps, makes twelve. The only difference between identical keys thus represented by flats and sharps, is that minute fraction of a tone existing between the augmentation of any note by a sharp, and the diminution of the succeeding note by a flat—the interval between the two notes being premised to be a full tone. The transposition from one of these keys to another is technically defined by the term, *inharmonic change*. Thus a transposition from Do sharp to Re flat, or from Re sharp to Mi flat, is an illustration of the change in question. As each of these pairs of notes are represented upon the piano and other keyed instruments by one key, the change or transposition alluded to has but a theoretical existence as far as these instruments are concerned; with stringed in-

struments, however, the case is quite different, and the distinction appreciable—one evidence of their greater perfection.

To those accustomed to keyed instruments, and who have not reflected upon the subject, the assertion of identity between keys represented by unequal numbers of flats and sharps, may seem paradoxical, inasmuch as it would appear that flats and sharps being represented by black keys exclusively, upon such instruments, the two sharps belonging to the key of Re, for instance, would require the use of two black keys, while the ten flats of its counterpart, the scale of Mi double flat, would require the employment of ten. This, however, is obviously an incorrect conclusion, for it must be recollected, that just as the black keys are required to represent either flats or sharps, as the case may be, so do the white keys represent double flats and double sharps, as well as the normal notes from which they derive their names—being the nearest approximation thereto, of which the imperfect construction of the instruments will admit.

For example: it will be found that in the scale of ten flats, or Mi double flat, there exist three notes twice flattened, viz: E, B, and A—together with the notes C and F, once flattened, all of which notes are to be represented by white keys. There remain, therefore, but two notes, D flat and G flat, to be represented by black keys, and these same keys are those brought into requisition in order to make the two sharps, F and C, belonging to the corresponding scale of Re natural.

The existence of corresponding keys, represented by flats and sharps, being thus sufficiently established, and the object of the writer being rather to analyze, than to suggest rules, the rationale of the one in question will now be investigated. In order to simplify the demonstration, and avoid the complication consequent upon the introduction of fractional quantities, the octave will be divided into the twelve semitones of which it is composed; a semitone being considered throughout the investigation as the unit of measure.

It will therefore be borne in mind, that the octave consists of twelve semitones; the fifth, of seven semitones; and the fourth, of five semitones, or units of measure. We shall commence our inquiry with the natural key of Do—that key affording one of the simplest forms for the application of the rule—and propose to show why the introduction of twelve sharps into the signature should restore the scale to the same keynote again—or rather, to its equivalent—the key of B sharp.

Now as the octave contains twelve semitones, and we have seen that the addition of each sharp raises the key a fifth, or seven semitones, it is evident that the addition of twelve sharps will raise the keynote a distance of eighty-four semitones. But eighty-four semitones is precisely seven octaves; the keynote therefore has completed its revolution of the circular octave, just seven times, and has thus reached the point whence it set out.

It is therefore clear, that the addition of twelve sharps to the natural key must restore the keynote to the position which it occupied originally.

We will now, however, take a more complicated example.

Suppose that one flat be introduced into the natural scale: we shall then have the key of Fa natural, and it is required to show by the addition of how many sharps, to the natural scale, the keynote may be made to reach a similar point.

As has already been seen, the addition of one flat advances the keynote the interval of a fourth, or five semitones, and the addition of each sharp, advances the keynote the interval of a fifth, or seven semitones. The keynote, therefore, by the addition of each sharp, performs a revolution of the octave, less five semitones. If, therefore, a sufficient number of incomplete revolutions be performed, so that this number multiplied by five—the number of units lost in each revolution—added to five—the number of units which the keynote is advanced by the flat introduced—shall be a sum divisible by seven without a remainder, then this number of revolutions, added to the multiple that this latter sum is of seven, must be the number of sharps required.

In the present instance, thirty-five being the product of five and seven—thirty-five less five—or thirty—is the number to be lost by the incomplete revolutions of the keynote—or in other words—by the addition of sharps to the signature. As five is lost in each revolution, six of these partial revolutions, or six sharps, will be required to accomplish this result. The number six, therefore, added to five—the number of times that seven is contained in thirty-five—making eleven, is the number of sharps required to place the keynote in the position to which it has been raised by the introduction of one flat into the signature of the natural scale.

For a third example, suppose that another flat be introduced into the signature. We shall then have modulated into the key of Si flat, and raised the keynote two fives, or ten semitones above its original position.

Now thirty-five less ten, equals twenty-five—and twenty-five is the number to be dropped by the revolutions of the keynote. Dropping five in each revolution, it will require five revolutions, or five sharps, to accomplish this. Five therefore added to five—the number of times that seven is contained in thirty-five—gives ten for the number of sharps required to form a key corresponding to the key of two flats.

From the examples given above, it is evident that thirty-five, or the product of five and seven, is a constant quantity in the formula, and, therefore, for every additional flat—or five that the key is advanced—five less of this product remains to be dropped by the revolutions of the keynote effected by the addition of sharps: and as twelve was shown to be the number of sharps required to produce a return of the keynote to the place which it occupied in the natural scale, so the introduction of every flat requires a corresponding omission of sharps for its equivalent key thus represented—that is, a number of sharps equal to twelve, less the number of flats introduced.

The investigation of the above rule evidently points to a property of numbers, which, in the case before us, is but specially applied. It may be thus generally enunciated.

If any number be divided into two parts, and also into other two parts; then will the difference between the product of the greater of the first division with the greater of the second, and the product of the lesser of the first division with the lesser of the second, be equal to the product of the whole number with the difference between the greater of either division and the lesser of the other: Also, will the difference between the products of the greater of each division with the lesser of the other division, equal the product of the whole number with the difference between the two greater, or the two lesser of each.

In the particular case before us, *twelve*—the number of units into which the octave has been divided—represents the whole number: seven and five—the number of semitones or units contained in a fourth and fifth respectively—represent the first division, which is constant. The second division—representing the number of flats and sharps required to produce corresponding keys—is variable.

For example: if four be the number of flats in a given key, then will four and eight represent the second or variable division. Here seven and eight will be the two greater, four and five the two lesser, and three, the difference between the greater of either division and the lesser of the other.

Hence, by the rule, we shall have seven multiplied by eight, less five multiplied by four, equal to thirty-six; and thirty-six equals three multiplied by twelve.

Thus, using the signs, $7 \times 8 - 5 \times 4 = 56 - 20 = 36 = 12 \times 3$.

Also, will eight multiplied by five—the product of the greater of one division with the lesser of the other—less seven multiplied by four—the lesser of the one with the greater of the other—equal twelve multiplied by one; or, the whole number multiplied by the difference between the two greater or the two lesser of the divisions.

Thus, $5 \times 8 - 7 \times 4 = 40 - 28 = 12 = 12 \times 1$.

The rule however, as before stated, is of general application; we will, therefore, apply it to some other number.

Suppose, for example, that fourteen be divided into two parts—ten and four—and into two other parts—eight and six. Then by the rule will ten multiplied by eight, less six multiplied by four, equal fourteen multiplied by four.

Thus, $10 \times 8 - 6 \times 4 = 80 - 24 = 56 = 14 \times 4$.

Also, ten multipled by six, less eight multiplied by four, equals fourteen multiplied by two.

Thus, $10 \times 6 - 8 \times 4 = 60 - 32 = 28 = 14 \times 2$.

Or generally, let a = any number, and let it be divided into two parts,

x = greater part, and
$(a - x)$ = lesser part.
Let y = greater part of the second division; then
$(a - y)$ = lesser " " "

Then $x\,y-(a-x)(a-y)=a\,[x-(a-y)]$; that is,

$x\,y-a^2+a\,x+a\,y-x\,y=a\,x-a^2+a\,y$, which, omitting the similar terms, reduces to $a=a$.

Also, $x(a-y)-y\,(a-x)=a\,(x-y)$; that is,

$a\,x-x\,y-a\,y+x\,y=a\,x-a\,y$, which, by reducting, results likewise in $a=a$.

The rule which we have above demonstrated may be proved in yet another way, without the introduction of semitones as units of measure.

It has already been seen, that in order to find the keynote required by any number of sharps, it is only necessary to divide, by seven, the product of this number of sharps with the number four, the remainder giving the number of notes intervening between Do natural and the keynote of the scale proposed.

It has also been shown that the number of flats, required to form a key corresponding with one represented by sharps, is the difference between the number of sharps and the number twelve; and further, that the product of this difference with the number three, divided by seven, will leave a remainder equal to the number of notes intervening between Do natural, and the keynote of this corresponding key of flats. It has also been shown, that this latter number will exceed by unity the number previously found, relating to the scale of sharps, for the simple reason, that a note considered as a sharp takes its name from the note preceding by one tone, the note from which the name of the same note considered as flat, would be derived.

These results furnish us with another formula which directs to a property of the number twelve; though not, as in the previous case, a property of general application.

It may be thus briefly stated:

If the number twelve be divided into any two parts, and also into its factors three and four; then will the remainder—after the division of the product of either of these parts with the lesser factor, by the sum of the factors—exceed by unity, the remainder—after the division of the product of the other part with the greater factor, by their sum.

Suppose for example, the number twelve be divided into two parts—eight and four; then will the remainder—after the division of the product of either eight or four with the lesser factor, three, by the sum for the factors, seven—exceed by one, the remainder, after the division by the same number, of the product of the other part with the factor four.

Thus, $4\times3=12$, $\frac{12}{7}=1$, with 5 for a remainder, which exceeds by *one* the number 4, which is the remainder of $\frac{8\times4}{7}=\frac{32}{7}=4+4$.

Likewise, $8 \times 3 = 24$, $\frac{24}{7} = 3$, with 3 for a remainder, which is greater by *one* than the remainder of $\frac{4 \times 4}{7} = \frac{16}{7} = 2 + 2$.

In every instance, as may be seen, the part multiplied by the lesser factor, when divided by the sum of the factors, has a remainder greater by one, than the remainder, after the division of the product of the other part with the greater factor, by their sum.

The property above stated, may, like its predecessor, be readily demonstrated analytically.

Thus, let a, be any part of the number twelve; then will $12 - a$, be the other part.

Let y, be the integral part of the division of the product of the part a, with the greater factor 4, by the sum of the factors 7—and let x, represent the numerator of the fractional part of the same division.

Let z, be the integer of the division, by the sum of the factors, of the product of the other part $12 - a$, with the lesser factor 3; then will $x + 1$ represent the numerator of the fractional part of said division.

By the hypothesis, $\frac{4 \times a}{7} = y + \frac{x}{7}$, from which we obtain

$$4a = 7y + x, \text{ or } x = 4a - 7y.$$

Also, by hypothesis $\frac{3(12 - a)}{7} = z + \frac{x+1}{7}$, whence

$$36 - 3a = 7z + x + 1, \text{ or by transposition,}$$
$$x = 36 - 3a - 7z - 1 = 4a - 7y. \text{ Whence,}$$
$$7a = 7y - 7z + 35, \text{ or } a = y - z + \frac{35}{7}.$$

From the conditions thus deduced, it is evident, that as y and z are by hypothesis whole numbers, their difference is likewise a whole number; and, that as $\frac{35}{7}$ is a whole number, the part a, must also be a whole number—for the difference between two integral numbers, increased by an integer, cannot be fractional; a, therefore, representing any part of twelve not fractional, the conditions will be fulfilled. Q. E. D.

The deductions further show, that the conditions essential to the possession of this property by a number, are, that the product of the number with its lesser factor, when diminished by unity, shall be divisible without a remainder by the sum of the factors; the factors differing from each other but by unity.

This latter property may likewise be shown to belong only to the number twelve. Thus, if y, and $y + 1$, be two factors of any whole number, then will their product be $y^2 + y$—and represent the number

—while $2y+1$, will be their sum. It is proposed to find such a value for the factor y, as shall render the fraction $\frac{y(y^2+y)-1}{2y+1}$, integral.

By actual division, we shall have, $\frac{y^2}{2}+\frac{y}{4}-\frac{1}{8}-\frac{7}{8(2y+1)}$, the integral qualification of which cannot be impaired by multiplying by 8. This performed, we shall have, $4y^2+2y-1-\frac{7}{2y+1}$ integral.

Now, as the first three terms of this formula are integral, (y being so by hypothesis,) they may be dispensed with, and there remains but the fractional form $\frac{7}{2y+1}$ to be considered. This last term will evidently be integral, if $2y+1=7$, or -7 (in which case $y=3$, or -4), or, if $2y+1=1$, or -1: in which case $y=0$, or -1, and the factor, $y+1=1$, or 0: in either event, one factor equaling 0, the number is imaginary.

In case $y=3$, or -4, $y+1=4$, or -3: the factors sought, therefore, are 3, and 4, or -3, and -4, the product of both of which is 12. Twelve, therefore, is the only number to which the property above enunciated belongs.

The investigation of this subject in its most general form, gives rise to the following problem:—

It is required to find two integral factors—differing from each other but by unity—any portion of the product of which, multiplied by the lesser factor and divided by their sum, shall have for the numerator of its fractional part, a sum greater by one than the numerator of the fractional part of the division, by the sum of the factors, of the product of the greater factor with the remaining portion of the product of the two factors.

Let y, and $y+1$, be the factors proposed; then y^2+y will be their product, and $2y+1$, their sum.

Let a represent any portion of the number y^2+y; then y^2+y-a will represent the remaining portion.

Let z and v represent respectively the integral portions of the two divisions, by the sum of the factors, of the products of the factors singly, with the parts into which the number y^2+y is divided; and let b represent the numerator of the fractional portion of the division by the sum of the factors, of the product resulting from the multiplication of the lesser factor with one portion of the number y^2+y.

Then, we have $\frac{(y^2+y-a)y}{2y+1}=z+\frac{b}{2y+1}$; and it is required to find such a value for y, as shall render $\frac{a(y+1)}{2y+1}=v+\frac{b-1}{2y+1}$.

By actual division, we have

$$\left.\frac{y^3+y^2-ay}{2y+1}=\frac{y^2}{2}+\frac{y}{4}-\frac{1}{8}-\frac{a}{2}+\frac{\frac{1}{8}+\frac{a}{2}}{2y+1}\right\} \quad . \quad . \quad . \quad 1;$$

and

$$\left.\frac{ay+a}{2y+1}=\frac{a}{2}+\frac{\frac{a}{2}}{2y+1}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad 2.$$

The fractions of the first of the formulæ will evidently vanish—except the fifth term—when multiplied by 8; and, in order that their relative values may be preserved, the second formula must likewise be multiplied by the same number. We shall thus have,

$$\left.4y^2+2y-4a-1+\frac{1+4a}{2y+1}\right\} \quad . \quad . \quad . \quad . \quad . \quad 3;$$

and

$$\left.4a+\frac{4a}{2y+1}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 4.$$

Now all the terms, but the last, in each of these formulæ, are evidently integral (a and y being assumed to be integral); and, as the condition imposed is, that the difference between the numerators of the fractional portions of these two divisions shall be *one*, it will now —since the multiplication by 8—have been increased eight-fold; and, as $1+4a>4a$, by 1; 7 added to $1+4a>4a$, by 8. The fractional portion of the third formula, therefore, must be increased by $\frac{7}{2y+1}$, in order that the conditions imposed may be fulfilled. But, if $\frac{7}{2y+1}$ be added to one term of the formula, it must necessarily be deducted from another; $\frac{7}{2y+1}$ must therefore be deducted from the integral portion of the third formula. Now, $\frac{7}{2y+1}$ is, in form, fractional, and cannot be deducted from an integral quantity without destroying its integrality, unless it be in itself integral. $\frac{7}{2y+1}$, therefore, is integral, and this, as before shown, gives $y=3$ or -4; and, for the factors required, 3 and 4, or -3 and -4. The product in either case is 12.

Twelve, therefore, is the number that may be divided in such a manner as to fulfil the conditions prescribed.

It is evident, from the above, that the formulæ introduced will remain unchanged, whatever may be the difference required in their fractional parts. In order, therefore, to find the lesser factor, the following general rule may be applied:—

Multiply the difference required, by eight, and deduct two from the product; one-half the remainder will be the factor required.

If c represent the difference proposed, and y the lesser factor, then $\frac{8c-2}{2} = y$.

Upon the subject of minor scales, there remains but little to be said. It is well known that the keynote of the relative minor of any major scale, is to be found a minor third, or three semitones, below that of the major proposed. In order, therefore, to find the number of sharps or flats required in the signature of any minor scale, it is only necessary to add three semitones to the keynote of such minor for the keynote of its relative major; having found this, the signature required will be readily discovered.

Any major key may be converted into a minor by the addition of three flats to the signature, observing that each flat is to be considered as canceling one sharp, where any sharps exist. Thus, the key of A natural is the key of three sharps; adding three flats to the signature precisely cancels the sharps existing: the key of A minor is the result.

Again: the key of two flats is the key of B flat major; three flats added to this forms the key of B flat minor. Now, the relative major of B flat minor, would be the key of D flat, which is likewise the key of five flats.

Again: any minor key may be converted into a major by the addition of three sharps to the signature, each sharp being considered as canceling one flat, where flats exist.

For example: to the signature of Do minor—which is three flats—add three sharps; the flats being canceled, the result is the key of Do major, or the natural key.

For a second example, to the signature of G minor—which is two flats—add three sharps, the flats already existing will cancel two of these sharps, leaving but one sharp in the signature. There results the key of one sharp, or of G major.

The flats and sharps alluded to in the above remarks, are those only which appear in the signatures of the respective scales, the accidentals being in no wise referred to.

The rules thus applied to minor scales, are in perfect accordance with the principles already investigated in this article. The addition of three flats to any major scale elevates the keynote precisely three semitones, or a minor third.

The keynote, therefore, corresponding to the scale thus modified, considered as a major, would be found just this minor third above its present position; the relative minor of this major would, consequently, be placed three semitones lower, or in the position which it occupied in the original scale. The keynote, therefore, by the addition of three flats, has remained unchanged; the scale alone having been changed from a major to a minor mode.

By the addition of three sharps to a *minor* scale, the effect is re-

versed, for the key by this means is *reduced* a minor third. As the keynote of the relative major of any minor scale is to be found three semitones above that of the minor, and as the introduction of sharps proposed reduces the keynote by a similar interval, it will, when thus modified, be found to occupy the same position which it held in the original minor scale—without alteration of the position of the keynote, therefore, the scale has been transposed from the minor to the major mode.

In the reduction of the keynote of a major scale, by three semitones, in order to find its relative minor, it is evident that the first semitone of the major scale which existed between the third and fourth, will be placed between the fifth and sixth of the new scale; the note that stood third in the major scale, thus becoming fifth in the minor. Unless modified by an accidental, these are the proper positions. There are thus but two full tones composing the interval between the first and second semitones of the minor mode, when uninfluenced by other flats or sharps than those already appearing in the signature, as required by the relative majors.

In the ascending scale, this arrangement does not obtain, a semitone being always required between the seventh and eighth, to effect which an accidental is indispensable. In the descending scale, the semitones, on the contrary, occupy precisely the positions indicated by the signatures of their relative majors. In these, therefore, the accidentals are omitted.

November, 1861.

On a Boiler, Engine, and Surface Condenser, for very high pressure Steam with great Expansion. By Alexander W. Williamson, Ph. D., and Mr. Loftus Perkins, of London.

From Newton's London Journal, Jan., 1862.

The boiler, engine, and surface condenser, forming the subject of the present paper, were designed, constructed, and worked by the authors with a view to promoting the adoption of very high pressure steam with great expansion; the engine is of 60 horse power, and works at a pressure of 500 pounds per square inch, as it was thought desirable to adopt at once appliances suited for considerably higher pressures than those proposed for general use. Although, however, it has been endeavored to make a boiler which would be safe at any attainable steam pressure, it is not considered necessary by the authors, for the present requirements of steam engines, to use pressures above 140 to 160 pounds per square inch; and the practical object of the present paper, is to give substantial grounds for confidence in working at such moderate pressures; and to show how, with steam at these moderate pressures, engines, free from the most serious drawbacks of ordinary expansive engines, can be made to work with a consumption of 1 to $1\frac{1}{4}$ pounds of coal per horse power per hour. As the use of impure fresh water or of salt water is attended with a variety of incon-

veniences and disadvantages, which are more serious the higher the pressure that the boiler is worked at, it appears indispensable to use a surface condenser for an engine working at high pressure; so as to condense, in a pure state, all the steam that goes out of the boiler, and supply nothing but distilled water by the feed pump; and several important incidental advantages are gained by this plan.

The boiler consists of a number of horizontal straight wrought iron tubes, arranged in sets in parallel layers. These tubes are welded up at the ends, and connected with one another by smaller vertical pipes. The tubes contain the water to be evaporated and the steam, while the fire is outside them. It is essential that the larger tubes be horizontal, or nearly so, and that each of them be connected to the next tube by means of two of the connecting pipes. The boiler contains five layers of tubes of $2\frac{1}{4}$ ins. internal diameter and 3 ins. external; the connecting pipes are $\frac{7}{8}$ in. internal diameter and $1\frac{3}{8}$ ins. external. In working, the water level is in the middle layer of tubes, and it remains free from the violent undulations which occur frequently in boilers where the internal space is not divided off. It is probable that a circulation establishes itself in the water, which rises with the bubbles of steam through the vertical connecting pipe at one end of the tube, and descends by itself through that at the other. The hot gases from the fire pass backwards and forwards between the layers of tubes, and remain long enough in contact with them to allow of a very good absorption of the heat. A similar boiler, used for some time, had eight layers of tubes above the fire. The boiler is thus made up of a number of vertical subdivisions arranged side by side, each containing five to eight parallel tubes. The several sections are all connected together at the bottom by means of a cross tube, with connecting pipes to each section, through which the water finds the same level in all the sections. The steam is taken off through a similar cross tube at the top of the boiler, with a connecting pipe to the highest tube of each section. All the sections are proved with water pressure up to 3000 lbs. per square inch.

The boiler has about 12 square feet of grate surface, but the total area of the air spaces between the bars does not amount to more than is supplied by six square feet of ordinary grate surface; and accordingly the fire is large but slack. The total heating surface amounts to 882 square feet. The capacity is about 40 cubic feet, half of which is water space and half steam room. The whole boiler is firmly held together by cast iron girders, and encased in non-conducting sides and top, made of four thicknesses of light plate, riveted together and kept about $\frac{3}{4}$ inch apart by ferrules, so as to form three closed air chambers. This arrangement is specially adapted for marine boilers.

The flue from the boiler is made to pass through a box containing the three cylinders of the engine, passing first down the small or high pressure cylinder, then up the middle one, and finally acting on the low pressure cylinder. The temperature of the gases in this box varies from 400° to 500° Fahr. After leaving the box, they pass downwards through a vertical square flue 10 feet long, giving up their remaining heat to the feed water, which is forced up through a wrought

iron coil of $\frac{7}{8}$-inch pipe contained in the flue, having 200 square feet of heating surface. At the bottom of this flue the gases enter a vertical iron funnel of 40 feet high and 24 inches diameter. The heat is so completely abstracted by the feed water coil, that, after leaving it, the gases have never been found hotter than 100° Fahr.

This small quantity of heat in the chimney gave sufficient draft to cause the evaporation of $8\frac{1}{2}$ cubic feet of water per hour in the boiler; but by the aid of a small fan, driven by a belt from the main shaft of the engine, the evaporation was usually kept at 15 cubic feet per hour. The evaporating power of the boiler was tested by means of a water metre, and, in an experiment of five hours duration, 390 lbs. of anthracite coal evaporated 420 gallons of water, which is about $10\frac{3}{4}$ lbs. of water per lb. of coal.

The great strength of this construction of boiler is the result of its being, in reality, an aggregate of a number of very small boilers. It absorbs the heat from the fire with the facility of a moderate thickness of iron, $\frac{3}{4}$-inch, without ever having a calcareous lining to keep the water away from the hot metal; while, at high pressures, it is exposed to less strain than ordinary boilers at comparatively low pressures. Thus, the shell of a cylindrical boiler of 5 feet diameter, or 26 times the internal diameter of these tubes, will be exposed to 26 times as great a strain as the sides of the tubes when containing steam of the same pressure; or at 19 lbs. pressure, it will have as great a strain as the tubes at 500 lbs. But even if tubular boilers were made so thin as to be equally liable to give way with large boilers, they would still be much safer to use; for if one of the tubes were to be destroyed, the water from the neighboring tubes would be driven out through the small connecting pipes, by which it is in communication with the rest of the boiler, in a very quiet sort of way compared with that in which the contents of a large boiler are thrown out when one of its ends gives way, or its shell is rent open. In fact, explosions, in the ordinary sense of the word, are impossible with these tubular boilers. It is well known, that tubes are more effective and safe when containing the water and steam within them, than when containing the hot gases from the furnace and exposed to an external pressure of the surrounding steam, since the tenacity of wrought iron is greater than its stiffness. The tubular boilers also admit of being easily and speedily repaired, by taking out a defective section and replacing it by a fresh section, or by new tubes kept in store for such contingencies.

The engine, of which drawings were shown, is of 60 horse power, and works at a pressure of 500 lbs. per square inch. It consists of three single-acting cylinders of 12 ins. stroke, all attached to a single cross-head, with a connecting rod at each end to the crank shaft. The steam passes through the three cylinders successively, the down stroke being made by the simultaneous action of the first and third cylinders, and the up stroke by the action of the middle cylinder alone; so that the three attached to the same cross-head act, as regards the rotation of the shaft, like one cylinder.

The steam, after having expanded in the down stroke above the

piston of the first cylinder of 6 ins. diameter, is allowed by the lifting of a conical valve, to pass under the piston of the second cylinder of 15 ins. diameter, and at the same time under the piston of the first; so that during the up stroke or working stroke of the second piston, the piston of the first cylinder is in equilibrium, and the steam is expanding into the second cylinder of six times the area. The valve between these cylinders then closes, leaving open the passage between the bottoms of both, while the first cylinder is receiving a fresh supply of steam from the boiler through the steam valve. At the same time, the valve between the second and third cylinders is lifted, and the steam allowed to pass above the pistons of both these cylinders, leaving the second piston in equilibrium and driving the third piston down. In the down stroke, therefore, there is the same pressure of steam in the top of the third cylinder, in both ends of the second cylinder, and in the bottom of the first cylinder. The bottom of the third cylinder is constantly in communication with the vacuum of the condenser. The third cylinder is of the same diameter as the second, so that at the end of the down stroke, the steam has expanded to about twelve times the volume of the first cylinder. When the down stroke is completed, a conical exhaust valve allows the steam from the top of the third cylinder, and also from the top of the second, to escape into the surface condenser; whilst the valve between the second and third cylinders falls to its seat, closing the passage between the bottom of the second and the tops of both. The whole effect, therefore, of this arrangement, which works with great simplicity, is, that in the up stroke, the first and third pistons are in equilibrium, and the second piston has the vacuum on the top of it; and in the down stroke, the second piston is in equilibrium, and the first piston works against a back pressure equal to the pressure of the steam on the top of the third piston.

Indicator diagrams from the three cylinders were exhibited—that from the first cylinder being taken from the passage between the first and second cylinders, as there was not room for fixing the indicator on the small cover of the first cylinder.

When the steam in the first cylinder is allowed to expand to four times its original volume during the down stroke, it has expanded to seven times as much, or twenty-eight times its original volume, by the end of the up stroke of the second cylinder; and hence a considerable fall of temperature necessarily takes place in the steam, with a consequent abstraction of heat from the inside of the first cylinder, and also from the bottom of the second, which is still further cooled by the expansion of the steam in the third cylinder to forty-eight times its original volume. Not only are the two last cylinders cooled by contact with steam which has lost heat by great expansion, and is reduced to a temperature considerably lower than that at which it entered the first cylinder, but still more by the evaporation at low pressures of the water deposited at the beginning of the stroke, by the condensation of steam upon the cooled sides of the cylinders. That water is contained in the bottom of the second cylinder, was proved by inserting a screw

cock at the lowest part of the passage between the second and third cylinders; and another proof is given by the remarkable fact that the quantity of steam, calculated from the end of the indicator diagram of each successive cylinder, is 6¾ cubic feet from the first, 9½ cubic feet from the second, and nearly 14 cubic feet from the third, showing that steam is condensed at the beginning of the stroke of the first and second cylinders, and subsequently evaporates into the next cylinder. The first and second cylinders together condense about half the steam,—a proportion which probably does not exceed the condensation of many condensing engines of far less expansion; yet, on account of the higher initial pressure of steam, the consumption of coal per horse power is only about 1½ lbs. per hour.

The engine was made to run fast, in order to allow little time for evaporation of internal moisture in the cylinders, between the strokes; and, in all respects, gives the most favorable trial to the principle of great expansion from a high pressure through a succession of cylinders communicating directly with each other. In order to preserve from injury the cotton packing of the rod that lifts the steam valve of the first cylinder, which is exposed to steam of very high temperature, a horizontal cast iron tube, about 18 inches long, is fixed to the valve chest above the cylinder, containing a steel shaft, with a cam on its inner end, which lifts the valve. The shaft nearly fills the cast iron tube, and all escape of steam is prevented by a stuffing box, packed with cotton, at the outer end of the tube, which always remains cold, since there is no passage of steam through the tube. This plan of lifting the valve is found perfectly effective and convenient.

For constructing larger engines, to expand a greater number of times effectively, the arrangement that is most advantageous depends upon the initial pressure of steam. If steam is used at 500 lbs. initial pressure, it is thought best, first to expand it down to about 125 lbs. pressure, in a couple of single-acting cylinders, connected, either on opposite cranks, or at opposite ends of a lever, so as to be equivalent in their action to one double-acting cylinder. The valves would be conical valves, lifted in the manner described above. From 125 lbs., the steam may then be expanded down further through a succession of double-acting cylinders with ordinary slide valves. But for most purposes, there is no doubt that sufficient economy of fuel can be attained by working at an initial pressure of 160 lbs., and by expanding the steam about 16 times, if it be done properly; and the appliances for this purpose are of the simplest kind, involving no novelty of construction, but merely of arrangement. It is submitted, that the mechanical and physical defects of all existing arrangements for getting more work than usual out of steam, by making it expand many times in one cylinder, may be avoided, and their object more fully carried out, by four common double-acting cylinders with simple slide valves. The cylinders would be of the same stroke, with areas in the proportion of 1, 2, 4, and 8, connected to four cranks on the same shaft, and with moderate sized tubular steam chambers, to dry and slightly superheat the steam between each cylinder. By making the first and

second cylinders work on opposite cranks, and close to each other, one would be pulling up while the other is pushing down, thus neutralizing the friction on the main journals. The third and fourth cylinders would likewise work on opposite cranks, set at right angles to the first pair, so as to distribute the power with uniformity throughout the whole revolution, the steam being cut off in each cylinder at two-thirds of the stroke. Each cylinder communicates with the next by means of a steam chamber, composed of drawn tubes connected together in the same manner as the tubes in the boiler already described, and placed in the flue from the boiler, for the purpose of superheating the steam to maintain the initial temperature throughout the whole expansion. Each steam chamber supplies steam to the next cylinder during the first part of the stroke, until the slide valve cuts it off, and allows the steam to expand during the remainder of the stroke; and, in each stroke, as much steam is supplied to the chamber, from the preceding cylinder, as goes out into the next cylinder. Thus, the supply of steam to the second cylinder being cut off at two-thirds of its stroke, which is also two-thirds of the exhaust stroke of the first cylinder, the remaining steam in the first cylinder and the intervening chamber is compressed into the chamber during the remaining third of the stroke, its pressure being thereby raised to the original pressure in that chamber, so that the next, and each succeeding stroke, of the second cylinder commences with the same pressure of steam. A similar process is carried out in the remaining cylinders and steam chambers.

When steam, in expanding through a succession of cylinders, with intervening steam chambers, leaves each cylinder at the same pressure as the steam in the chamber into which it passes, it necessarily gives theoretically the same gross work on the pistons as if it expanded to the same amount in a single cylinder. Practically, however, it is impossible to expand so much as 16 times in one cylinder, without introducing many serious evils, which bring down the power to a mere fraction of its theoretical amount: whereas the expansion of the steam to double its volume in one cylinder, can be carried out without difficulty or inconvenience.

The degree to which the steam will be superheated in the intermediate steam chambers depends on the temperature of the flue in which they are placed; but as the tubular boiler exposes a large extent of heating surface to the action of the hot gases from the fire, before they come in contact with the steam chambers, no inconvenient amount of superheating is likely to occur, nor any burning out of the chambers. It is desirable to arrange the superheaters, so that the hot gases may come in contact with them, in the same order in which the steam goes through them, so as to act last on the coolest steam chamber.

The surface condenser used with the engine above described consists of a number of straight wrought iron tubes, fixed vertically in a chamber, closed at the upper ends, and screwed by their open ends into a thick plate at the bottom. These tubes contain the cold water,

which circulates rapidly through them, and their outer surfaces are exposed to the steam to be condensed. Each of the tubes contains a smaller tube, open at both ends, and through this inner tube the condensing water is driven up by the pump to the top of the outer tube, and then descends through the annular space between the tubes. This arrangement prevents the possibility of any straining, and consequent leakage, of the tubes, from heating or unequal expansion, by having all the tubes fixed at one end only, with the other end left free. The condenser in use has about 20 square feet of cooling surface for every cubic foot of water condensed per hour, and the vacuum obtained by it varies from 26½ to 28½ inches of mercury, notwithstanding that the air pump is exceedingly small in proportion.

An incidental, but not unimportant advantage of using a surface condenser is, that it keeps the water level in the boiler constant, without any trouble to the engineer, by always returning to the boiler the exact quantity of water that has been taken out as steam. For circulating the water through the tubes of the condenser, the arrangement best suited for marine engines is a lift pump or air pump, to draw the sea water through them, with a screw cock on the inlet pipe, by which the supply of water can at pleasure be throttled: so that, even were a leakage to arise in the tubes of the condenser, no sea water could get in to mix with the distilled water, but, on the contrary, an outward leakage would occur, if care were taken to keep the vacuum inside the tubes a little better than that in the condenser. In order to supply the place of any distilled water that might escape by leakage or otherwise, a small still should be attached to the boiler, heated by means of a coil of steam pipe, of which one end communicates with the steam room of the boiler, whilst the other is over the hot well, and is provided with a screw cock. As soon as this cock is allowed to drip or run, the still will begin to work, and replenish the boiler with distilled water, through the usual channel of the condenser.

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Mr. E. A. Cowper observed, that the advantages of high pressure steam were now generally acknowledged, and the pressure of steam in engines had been gradually raised, having risen now in locomotives from 100 lbs. to 150 and even 200 lbs. per square inch. He, therefore, thought it was desirable to look boldly at the advantages of a much higher pressure, as had been done in the paper just read, where it was proposed to work with 500 lbs. steam, and the engine described had been worked at that pressure, to show the advantages practically. The boiler he had seen working at that pressure, and it certainly appeared a very strong construction. With a high pressure of steam, he had long considered the use of a surface condenser and distilled water in the boiler essential to economy, and it was attended with advantages of great importance. The necessity for cleaning the boilers was done away with, as no deposit could ever be formed, and the water level was maintained constant, whatever quantity of steam was taken off by the engine, while there was only $\frac{1}{25}$th as much water to pump out of the condenser, and, what was even of greater importance, the pump-

ing out of the air, introduced with the injection water in ordinary condensers, was saved.

Mr. Perkins said, the indicator diagram, shown from the first cylinder, was taken from the passage between the valve and cylinder, because there was not room to get the indicator on the top of so small a cylinder. The boiler pressure was 570 lbs., and the spring of the indicator made the figure jump up to 600 lbs. when the steam was admitted, but the actual pressure was only 510 lbs. total at the time of cutting off. The steam was cut off at one-fourth of the stroke in the first cylinder, and expanded down to 170 lbs. total pressure, or about three times, when it was exhausted into the second cylinder, the pressure dropping to 88 lbs. total in the passage between the cylinders; from the second cylinder it was exhausted at 36 lbs., and dropped to 30 lbs. in the passage to the third cylinder, from which it was let out into the condenser at a pressure of 27 lbs. total, making the whole expansion from the commencement amount to about nineteen times.

Mr. E. A. Cowper remarked, that as the pipe from the cylinder to the indicator was long, there might be an accumulation of water in it, which would cause the indicator to jump by its momentum. He inquired whether the drop in the pressure, in exhausting from one cylinder into the next, was owing to the passage between the cylinders being large.

Mr. Perkins replied, that the passages were not large, but the drop was occasioned by the steam being cooled, from want of sufficient heat in the casing to maintain the temperature. The pipe from the cylinder to the indicator had to be made long, in order to keep the packing of the indicator from being burnt by the high temperature of the steam; consequently, the pressure was probably somewhat lower in the indicator than in the cylinder. The engine had not yet been applied to regular work, but had been working experimentally during the last six months with a friction break. to test the practicability of the plan. The cost was about the same as that of marine engines, namely, £50 to £60 per nominal horse power, including the boiler; the engine indicating, however, from $2\frac{1}{2}$ to 3 times the nominal horse power.

Mr. E. A. Cowper observed, that the larger engine suggested in the paper, with the steam expanded through four cylinders, working in pairs, on cranks at right angles, would give a very uniform driving power, with probably only from 10 to 25 per cent. variation in driving power throughout the revolution, according to the point of cutting off in each cylinder.

Mr. W. May had seen the engine at work, when it was driving the friction break, and it appeared a useful step towards improved economy in steam engines, by showing the practicability of much greater pressure and expansion, whether the details of construction at present adopted were considered the best or not. The boiler seemed in good order, and perfectly safe for the high pressure of steam. It could be easily repaired, by the removal of any portion, without interfering with the rest of the boiler. The temperature of the chimney

was remarkably low, the iron casing being so cool that the hand could be borne on it.

Mr. F. J. Bramwell had seen the engine at work, and considered it useful and interesting in illustrating the economy of steam power, by using increased pressure and greater expansion. The mode of estimating the evaporative duty of the boiler, by measuring the consumption of water with a metre, he thought was liable to error, if not checked by observing the total increase of heat in the condensing water, in order to allow for water carried over as priming, which otherwise made the evaporative results appear greater than they really were. It was necessary to adopt this check in calculating the evaporative duty, because priming was sure to occur, except in boilers with very large steam room, where there was no violent ebullition. He had known an instance where the boilers in some of the American steamers, made with a number of vertical tubes, had been stated to give a very high evaporative duty; but when their actual performance was tested with a metre, it was found that 43 lbs. of water were fed into the boiler per indicated horse power per hour, which certainly could never have been all converted into steam, but showed that priming must have taken place extensively, and that the apparent high evaporative duty was a mistake.

Proc. Mech. Eng. Soc., May 2, 1861.

On the Manufacture of Steel Rails and Armor Plates. By Mr. JOHN BROWN, of Sheffield, Eng.

From Newton's London Journal, February, 1862.

Steel Rails.—One of the most important items in the cost of railway maintenance is the renewal of rails, and it is therefore natural that much attention should have been paid to the various methods proposed for giving greater durability to the rail. Experience has shown the want of some means by which their duration could be prolonged; and in the manufacture of rails it is always now expected that the quality of the material and the method of piling shall be distinctly stated before any large amount of work is undertaken.

No ordinary material or method of piling or making the finished rail will, however, resist the crushing action of modern locomotives; and extraordinary means have been sought to accomplish this much desired object. Amongst the most important of the methods hitherto used for this purpose is that of forming the wearing surface of the rail entirely of steel, by introducing a bar of steel into the pile, and rolling it out so as to unite it with the iron body of the rail. Another method is to submit the surface of the ordinary iron rail to a process of conversion in a furnace specially adapted, thereby case-hardening the outer skin of the wearing portion of the rail. Both of these processes have many advocates, and to a certain extent they fulfil their object; still, they are open to the serious objection that only the crust or skin of the rail is rendered hard, and they do not prevent the body of the rail from yielding to the severe pressure of the wheels; lamina-

tion and splitting are only to a small extent diminished, and though the life of the rail is prolonged, the prolongation is uncertain. The same objections apply to the puddled steel rail, and it is also liable to vary considerably in its hardness, and to be at times too brittle for perfect safety. This liability to vary in quality is inseparable from the mode of manufacture as at present practised; and though many very good rails of this kind have been produced, the want of certainty in the manufacturing process seriously diminishes its value.

The introduction, however, of Bessemer's system has opened out a mode of producing a pure, homogeneous, hard, and tough material, most admirably suited for the manufacture of rails; and though their cost may for a time prevent their being extensively used, there is no doubt that on every railway there are certain places where they would be laid with economy, where the traffic is so constantly severe that ordinary points and crossings have to be renewed on an average four times a year. Once laid of cast steel rails, they would give no trouble for many years.

In the Bessemer process, the pig metal is reduced in a reverberatory furnace, and is then run by a trough into the blowing or converting vessel, in which air is forced through the fluid metal for about twenty minutes, or until the fluid pig is almost entirely decarbonized. A small quantity of melted pig containing a known proportion of carbon, is then added, and the charge of converted metal is then transferred to a ladle, from which it is poured into ingot moulds; not, however, by the usual mode of canting the ladle, but by opening a valve in the bottom of the ladle, which allows only the pure metal to run out into the moulds. The ingots are cast of such weight and form as are necessary for the production of each rail. Thus, for a 6-yard rail of 84 lbs. per yard, the ingot requires to be 9 inches square and 26 inches long. This ingot is hammered down to 6 inches square and 5 feet long, and then rolled in the ordinary way. It will be evident, that the only limit to the length of the rail made in this simple manner is either the weight of the ingot which can be produced, or the length of the rolling mill or heating furnace. It is as easy to produce long lengths as short ones; and in this respect the above method has some advantage over piling.

There is no tendency to lamination in this perfectly homogeneous material, and its toughness and ductility are remarkably shown by the specimens exhibited, all of which were twisted and bent when cold. Its tensile strength is upwards of 40 tons per square inch.

Cast steel rails are not an entire novelty; for several years ago a few were made at Ebbw Vale, and were laid at the bridge at the north end of the Derby station, and there they are at the present time perfectly sound and good, whilst the neighboring iron rails have been many times worn out and replaced. But these rails were made, at a great expense, from ingots cast in the old or usual method, and the imperfect appliances then existing made it impossible to introduce them commercially. Still, the experiment at Ebbw Vale has clearly proved the far greater power of resisting wear and tear possessed by

the steel rails; and now the method of producing ingots by the Bessemer process enables rails to be produced which bid fair to become in truth a really "permanent way."

Armor Plates.—In the further portion of the present paper, on the manufacture of armor plates, the writer's principal object is to elicit discussion upon this important subject; and as but a very short time has elapsed since the rival powers of the penetration of shot, and the resistance of plates, have been so seriously and energetically tested, it is necessary to speak with diffidence upon a matter which on all hands is allowed to be as yet imperfectly determined. No limit has yet been assigned to the magnitude of future artillery, nor has any degree of impenetrability of iron plates been declared unattainable. The manufacturer's business is simply to make the best and strongest armor which at the present time is wanted; his problem being how to produce the largest plate of iron of the maximum degree of toughness.

Two methods of producing large masses of wrought iron have been in use: the first by the process of building up under the steam hammer, and the second by building up under the rolls. Under the steam hammer, the plate is produced by welding together lumps or masses of scrap iron; each mass of scrap being added and welded to the end of the plate, until it reaches the required length. Plates made in this way have been seriously objected to on account of their brittleness; and it is reasonable to suppose that this mode of manufacture is somewhat likely to induce brittleness. There can hardly be any continuity of fibre in a plate forged from masses of scrap iron, perhaps of different qualities, each at different heats; the nature of the weld and its form, and the repeated cooling and re-heating of the plate, are also adverse to its possessing great toughness. The rolled plates have been found more uniform in quality and of greater toughness than the hammered; and though the difficulties in the manufacture are grave, there is no departure from the ordinary practice followed in making large plates for other purposes. The difficulties which do exist are chiefly due to the immense weight and size, and the intolerable heat of the mass, which must be dealt with while at a welding temperature.

The general size of the armor plates required for the plated frigates is from 15 ft. to 18 ft. long, from 2 ft. 6 ins. to 3 ft. 10 ins. wide, and 4½ ins. thick. The weight, therefore, of the finished plate ranges from 60 to 110 cwts.; and in the unfinished state it comes from the rolls at 80 to 140 cwts. From 3 to 4 ins. is cut off the sides, and 10 or 12 ins. from each end; and in this item of waste, the hammering process has an advantage over the rolling.

The mode of manufacture of a 5-ton plate is as follows:—Bars of iron are rolled 12 ins. broad by 1 in. thick, and are sheared to 30 ins. long. Five of these bars are piled and rolled down to a rough slab. Five other bars are rolled down to another rough slab, and these two slabs are then welded and rolled down to a plate of 1¼ inches thick, which is sheared to 4 feet square. Four plates like this are then piled and rolled down to one plate of 8 feet by 4 feet, and 2½ ins. thick; and lastly, four of these are piled and rolled to form the final entire plate.

There are thus welded up together 160 thicknesses of plate, each of which was originally 1 in. thick, to form the finished 4½ ins., making a reduction of 35 times in thickness; and in this operation from 3500 to 4000 square feet of surface have to be perfectly welded by the process of rolling. It is not surprising that, even with the greatest care, blisters and imperfect welds should exist, and render the plate defective; this is the chief difficulty to be overcome, and a very serious one it is; and as the magnitude and weight of the plate increase, so does also the liability to failure.

The final operation of welding the four plates of 8 feet by 4 feet by 2½ inches, is a very critical matter. To bring a pile of four plates of these dimensions up to a perfect welding heat all through the mass, without burning the edges and ends of the plates most exposed to the fire; to drag this pile out of the furnace, convey it to the rolls, and force it between them, in so short a time as to avoid its losing the welding heat, is a matter of greater difficulty than those unacquainted with the work would imagine. The intensity of the heat thrown off is almost unendurable, and the loss of a few moments in the conveyance of the pile from the furnace to the rolls is fatal to the success of the operation.

At the writer's works, the pile of four plates, which united form the finished plate, is heated in a special furnace, and is drawn out by a liberating chain on to an iron carriage, which conveys the pile to the rolls. The carriage travels upon a line of rails let into the ground; and close in front of the roll frame is a small incline upon the railway, which lifts up the front of the carriage at the moment of its arrival at the rolls, and enables it to deliver the pile upon the fore-plate. As the plate passes through the rolls, it is received on the other side upon a roller frame, which is set at a considerable elevation towards the rolls, so that the tendency of the plate is to return. The rolls are then reversed, and the plate, which was pressing against them, passes back through, and is received upon the carriage; and again the operation is repeated, until the 10 ins. thickness is reduced to 4½ ins.

The plate is then lifted off the carriage by a crane, and deposited upon a massive cast iron straightening bed; and an iron cylinder, weighing 9 tons, is rolled over it to and fro by hand levers, until the curvature which the plate has acquired in the rolling, is entirely removed. As soon as the plate is sufficiently cool, it is lifted off the straightening bed by another crane, and laid upon a planing machine, where the final operation of planing its sides and ends are completed.

—

Mr. Brown exhibited specimens of the steel rails, fractured, to show the quality of the metal; and pieces of the rails that had been bent double while cold without fracture: also, a piece of 75 lbs. double-headed rail which had been drawn down hot into a bar 1 inch square, and then twisted cold without showing any tendency to cracking or splitting. In answer to a question of the Chairman, he said that they had been used hitherto mainly on the continent; those longest laid had been down about six or seven months at the new Pimlico Railway

Station in London, and had proved very satisfactory: they were in as good condition now as when first laid; and a set of steel points and crossings had also been in constant use for seven months at the same station. There were also some of the steel rails more recently laid on the Caledonian, Lancashire and Yorkshire, London and North-Western, and Rhymney Railways; but these had not yet been down long enough to afford any results as to their durability. The rails showed not the least brittleness, but were much tougher than wrought iron rails. The fractured rails exhibited were purposely broken at the time of rolling, to show the quality of metal: and its great toughness was proved by the rails exhibited, which were all bent and twisted cold. The cost of the rails was, of course, higher than that of ordinary rails, and was an objection against them on the English railways; but continental companies were willing to pay the extra first cost of a more expensive rail, provided it would wear better than the ordinary rails, and he believed the steel rails would wear out at least five ordinary rails; but none of the steel rails had been used up yet, and their durability could therefore only be estimated from their comparative appearance after a short time of wear. The price of the rails was £18 10*s.* per ton in England, and £5 or £6 more on the Continent.

Col. Kennedy inquired what reduction of weight it was considered could be safely made in the rails by the use of steel instead of the ordinary wrought iron rails.

Mr. Brown said, the weight was reduced about one-third as compared with ordinary wrought iron rails. The 75 lbs. double-headed steel rails had been tested up to 80 tons in the centre, with 3 feet length between the bearings, and the deflection was $2\frac{3}{4}$ or 3 ins., without showing any signs of cracking.

Mr. J. Fenton asked how the 80 tons load was applied, whether by hydraulic pressure or by dead weights, and how it was measured; with hydraulic pressure, it was sometimes difficult to ascertain the pressure correctly, in measuring by safety valves. He inquired also whether the ends of the rails were fixed in the bearings during testing.

Mr. Brown said the load was applied by hydraulic pressure, and measured by two safety valves—the valve of the press, and a separate valve on Mr. Naylor's plan, fixed on purposely for the experiment, to prevent any risk or mistake. The rails were simply supported on the bearings in testing, with the ends left free.

The Chairman inquired, in reference to the manufacture of the armor plates, what was the quantity of work that could be done in rolling the plates, and how many were produced per day in regular work.

Mr. Brown replied, that in ordinary work, with the one mill now in operation, three plates were turned out per day of 12 hours, weighing 5 or 6 tons each; if working all the 24 hours, 5 or perhaps 6 plates per day might be made, but this would require a second furnace for heating the plates, to allow of stopping and cleaning one furnace without delaying the work.

In answer to an inquiry of Col. Kennedy, as to what experiments

had been made on these armor plates, to determine their power of resisting shot, Mr. Brown remarked, that two armor plates, tried at Portsmouth in July, had proved, to a certain extent, successful. The plates were 4½ inches thick, backed by 18 inches thickness of teak, and were fired at with shot 68 lbs. weight, from a 95 cwts. smooth-bore gun of 8 ins. bore, with 16 lbs. charge of powder, at 200 yards range. The first plate was 7 feet 9 ins. long by 3 feet 2 ins. wide: the first shot hit near a corner of the plate, at a place where the weld was imperfect, and indented the iron to some depth; the second shot also hit near the same place, and indented the plate; the third shot struck the plate in the centre, and made a hole right through the iron, making a crack all round the opening; the fourth shot hit near the bottom, and broke the lower edge of the plate in; and the fifth shot happened to go through the hole made by the third. The second plate was nearly double the length of the first, being 14 feet long by 3 feet 7 inches wide: the first shot indented the plate 3 inches, and broke out the iron at the centre of the indentation; the second shot punched right through, and broke the backing; and the third and fourth shots each broke out a hole of 12 ins. diameter, and smashed the backing. A portion, broken off one of the plates, was exhibited, which showed that the iron was much more fibrous than in the plates on which experiments had first been made, and still more favorable results were expected if the iron could be kept in a thoroughly fibrous state, so as to have a soft and tough quality, which was less easy to fracture than a hard and brittle metal.

Two of the armor plates were in the hands of the Admiralty for further experiments; and trials had been made at Shoeburyness of two of the plates 5 inches thick, which had proved altogether most satisfactory as to the tenacity and toughness of the plates. The object was, to produce armor plates capable of resisting guns of increased power; and the experiments now made seemed to show that this might be effectually accomplished by the mode of manufacture that had been described.

The Chairman observed, that the quality of the plate could be better judged of when it had been actually pierced in the experiments than when only indented, as they could then see the character of the hole, and examine minutely the completeness of welding of the several thicknesses. He inquired whether the Bessemer steel had been tried for the armor plates.

Mr. Brown had not yet tried it for the armor plates, but expected to do so shortly, when he had a hammer heavy enough for working it; he intended using a 4-ton Naylor's steam hammer, with the steam admitted above the top of the piston, in the fall, to increase the force of the blow.

The Chairman remarked, that he felt a great interest in the manufacture of the armor plates, as he was himself engaged, on the other hand, in endeavoring to increase the power of guns so as to penetrate the strongest plates that could be made. As regarded the mode of manufacturing the plates, he had seen and examined those which had

been fractured in the experiments, and his own observations at present were unfavorable to rolling the several thicknesses together to form the plates, as not giving pressure enough to insure a thorough welding in all parts. Moreover, the extent of surface to be welded, amounting to 3000 or 4000 square feet in the entire manufacture of a single plate, was so great, that it was difficult to conceive how a perfect weld could ever be obtained throughout, as it seemed impossible to insure an entire exclusion of dirt from between the plates, and unless they were kept quite clean, they could not be welded into a single homogeneous plate. The difference in resisting power was very great between a really homogeneous material and one having any lamination of structure; in the latter case, all portions of the material did not take their share of the strain in resisting a blow, but some were more severely strained than the rest, causing them to give way sooner; and a series of thinner plates, though making up a considerably greater total thickness, was inferior to a single homogeneous plate in resisting power. The very best plates he had seen at present were some small forged plates, worked under a hammer at Portsmouth Dockyard; these were thoroughly sound in all parts, and free from impurities. What was wanted for the armor plates was a perfectly homogeneous material, and of soft texture; if they could be made, like the steel rails that had been described, from a single mass of thoroughly homogeneous metal, he thought there might be a good prospect of success. Ordinary cast steel, however, he did not think would be so suitable as good wrought iron, on account of not being soft enough.

For forging the metal of the armor plates under the hammer, he considered the weight of the hammer was of the greatest importance; and in reference to the use of a 4-ton hammer, with steam above the piston to increase the blow, it had to be borne in mind, that the steam increased only the velocity of the blow without adding to the mass falling, which was not the result required; he feared the effect would be, that the force of the blow would be spent on the surface of the material, and would not go through to the centre of the mass like the blow of a heavier weight falling with a proportionately smaller velocity. This appeared to him a very important consideration in forging large masses, however effective that kind of steam hammer undoubtedly was for lighter work.

Proceedings Insti. Mech. Engineers, July 31, 1861.

Puddled Steel, Homogeneous Iron, and Steel Iron.

From the Lond. Civ. Eng. and Arch. Journal, February, 1862.

The question of the mechanical properties of puddled steel, as also the less highly carbonized products of iron, is one of growing importance. Cheap and ready manufacture and a high degree of strength are advantages claimed for this class of material, and its field of application is becoming largely extended. An accurate acquaintance with the limits of strength and laws of elasticity becomes therefore increasingly desirable.

We have before us a pamphlet by Mr. W. H. Barlow, F. R. S., M. I. C. E., giving an account of some experiments which he has conducted by permission of the Royal Arsenal at Woolwich, for the purpose of obtaining some reliable data upon this subject. The testing machine employed at Woolwich is a counterpart of that used by the United States Government for ascertaining the strength of cast iron. It records accurately the amounts of the ultimate resistances to rupture by tension, compression, transverse strain, and torsion, but is not well arranged for exhibiting the progressive action of the three first named kinds of strain. Consequently, as Mr. Barlow states, although the experiments may be relied on as far as they go, and point out the more important properties of the materials tested, they do not afford all the data that could be wished; as puddled steel rarely yields to rupture in the testing machine except under tension.

"Puddled steel is made direct from cast iron by a process analogous to that used in obtaining common wrought iron, but instead of expelling all the carbon, such an amount is left contained as to impart the quality of the steel to the metal so treated. Considerable experience is required in the selection of suitable qualities of metal, and also to know the precise moment at which to stop the process of decarbonization in the puddling furnace; and other conditions have to be observed in order to secure the success of the operation; but it is now accomplished with great certainty, and the result is the production at a very low cost of steel, which, although not of high quality, is nevertheless possessed of many valuable properties.

"In addition to the experiments on puddled steel, similar experiments were made on homogeneous metal and steel iron, and on puddled steel melted and cast into ingots. Steel iron is a condition of the metal when the process of decarbonization is carried further than in puddled steel; its fracture is fibrous, and it approaches very nearly to wrought iron. The other materials above mentioned show a crystalline fracture, the crystals being very small, fine, and regular, like that of gun metal. The steel possesses also similar properties of malleability, although much harder and of much greater strength than gun metal."

The following table (I.) is an abridgment of Mr. Barlow's summary of the experiments on tension:—

TABLE I.—*Summary of Experiments on the Resistance to Tension of Puddled Steel, &c.*

No. of experim't.	Name of Material.	Name of Maker.	Ultimate Strain per sq. inch.	Mean.	Remarks.
			lbs.	lbs.	
52 to 56	Puddled steel, . .	Mersey Iron Works,	84,152 to 109,117	95,233	Fracture crystalline.
19 " 23	Homogeneous metal,	Firth & Co., . .	88,640 " 115,133	100,994	" "
29 " 34	Puddled steel, . .	Naylor & Vickers,	100,931 " 133,054	116,336	" "
57 " 61	Puddled steel melted and cast into ingots,	Naylor & Vickers,	84,652 " 124,492	101,753	" "
8 " 12	Steel iron, . . .	Atlas Works, . .	67,487 " 71,158	69,456	" fibrous

From these results the author draws the following conclusions:—

"From the above experiments it appears that the ultimate tensile

strength of puddled steel, homogeneous metal, and puddled steel melted and cast into ingots, is nearly double that of wrought iron. The variation of strength in the different samples is not greater than is found to arise in wrought iron.

"Several specimens taken out and remeasured after receiving strain, indicate that permanent set first begins to be perceptible at 20,000 lbs. per square inch.

"Puddled steel and homogeneous metal broke with a fracture presenting a minute crystalline appearance; and there were two distinct forms of fracture, one being in a plane at right angles to the line of strain, and the other a cup-shaped fracture more or less perfect.

"The material called 'steel iron' showed a fibrous fracture, and was of much less strength than puddled steel and homogeneous metal. In this material it was evident that the process of decarbonization had been carried too far, and that it differed but little from iron of good quality."

From the summary of experiments on compression we extract the mean results (table II.):—

TABLE II.—*Summary of Experiments on the Resistance to Compression of Puddled Steel, &c.*

No. of experim't.	Name of Material.	Name of Maker.	Pressure per sq. in.	Amount of Compression.	Rate of Compression per ton per sq.in. in terms of length.
			lbs.	inch.	
47 to 51	Puddled steel (mean length, 1·323 ins.),	Mersey Iron W'ks,	21,908	·0032	·000247
35 " 38	Puddled steel (mean length, 1·368 ins.),	Naylor & Vickers,	20,196	·00325	·000263
24	Homogeneous metal (length, 1·295 ins.),	Firth & Co.,	22,514	·003	·000231
62 to 65	Puddled steel melted and cast into ingots (mean length, 1·4175 ins.),	Naylor & Vickers,	21,998	·00575	·000413
13, 17, & 18,	Steel iron (mean length, 1·102 ins.),	Atlas Works,	23,574	·00533	·000459

"The samples tested were all about $1\frac{1}{3}$ inches in length. The approach of the steel pistons between which the samples were compressed was carefully measured, and the results as recorded are correct as showing the compressions of columns of the length employed. The amount of compression per ton per inch is however so great, and being moreover inconsistent with that which may be inferred from the experiments on transverse strain, it is to be presumed that the result is affected by the short length of the samples. The effect of the pressure is to enlarge the diameter at the centre of the sample.

"Fig. 1 represents the sample No. 24 before pressure was applied, and fig. 2 is the same sample after receiving a pressure of 51 tons per inch, and similar effects, though in a less degree, result from smaller pressures. It is known that in long bars subjected to compression the centre portion is not proportionately expanded, and it follows that the decrease of length in short columns will not be proportional to that in long ones. It is evident, however, that the puddled steel and homogeneous metal are less compressible than cast puddled steel

Fig. 1.

Fig. 2.

and steel iron. Puddled steel, whether cast or otherwise, could not be crushed with any pressure the machine was capable of exerting; the only effect was to produce an alteration in the form of the sample. This property would indicate that if great pressure were to be resisted, it might be advantageous to submit the material to great compression before using it. The effect of the pressure appears to produce a re-arrangement of the particles, and when so re-arranged, they are capable of sustaining greater pressure than in their original form."

TABLE III.—*Summary of Experiments on the Resistance to Transverse Strain of Puddled Steel, &c.*

No. of experiment.	Description of Material.	Name of Maker.	Mean Breadth.	Mean Depth.	Deflection produced by 7500 lbs.	Value of E*	Weight at which Deflection ceases to be regular.
			ins.	ins.	ins.		lbs.
39	Puddled steel,	Naylor and Vickers,	1·935	1·9275	·055		16,000
40	do.,	do.,	1·925	1·9600	·040		16,000
41	do.,	do.,	1 985	1·9750	·040		18,000
		Mean,	1·945	1·9542	·045	2,870,500	16,666
42	Homogeneous metal,	Firth & Co.,	1·955	1·960	·030		14,000
43	do.,	do.,	1·965	1·970	·060		14,000
44	do.,	do.,	1·960	1·980	·035		18,000
		Mean,	1·960	1·970	·042	2,979,200	15,333
2	Puddled steel,	Atlas Works,	2·110	2·085	·037		16,000
3	do.,	do.,	2 055	2·050	·042		16,000
		Mean,	2 082	2 062	·040	2,568,000	16,000
					Deflection produced by 5800 lbs.		
4	Puddled steel,	Atlas Works,	·975	1·985	·062		8,000
5	do.,	do.,	1·035	2 020	·055		9,000
		Mean,	1 005	2 002	·058	3,100,200	8,500
					Deflection produced by 2300 lbs.		
6	Puddled steel,	Atlas Works,	2·010	1·005	·065		3,500
7	do.,	do.,	1·975	·960	·083		3,500
		Mean,	1·992	·982	·074	2,838,000	3,500

*The value of E is obtained from the formula $E = \frac{l^3 w}{32 b d^3 s}$ [See "Barlow's Strength of Materials."]

"By comparing these experiments (Table III.) with those of Prof. Barlow on wrought iron bars 2 inches square (see Barlow on the Strength of Materials), it will be seen that the deflection under transverse strain is greater in puddled steel, when of like dimensions and under like circumstances, in the ratio of 10 to 11. But the weight it is capable of sustaining before the increments of deflection with equal weights cease to be regular is, as nearly as possible, double that of wrought iron. Hence, so far as these experiments go, it would appear that a bar of puddled steel may be bent about twice as much as a bar of iron of like dimensions, without impairing its elasticity, or without causing a greater permanent set."

In the above experiments the weight was applied at the centre in each case, and the distance between bearings was 20 inches.

SPECIFIC GRAVITY.

"The specific gravity was ascertained to be as follows:—

Puddled steel,	1st sample,		7·7805
" "	2d "		7·7836
Steel iron,	1st "		7·7431
" "	2d "		7·7580

TABLE IV.—*Resistance to Torsion.—Puddled Steel.*

Weight applied at 25 inches from centre.	Firth & Sons. Diameter, 1·763 inches.		Naylor & Vickers. Diameter, 1·864 inches.		Naylor & Vickers. Diameter, 1·861 inches.		Naylor & Vickers. Diameter, 1·876 inches.	
	Deflection.	Permanent set.	Deflection.	Permanent set.	Deflection.	Permanent set.	Deflection.	Permanent set.
lbs.	Deg.							
100	·25		·00		·00		·10	
200	·20		·25		·15		·40	
300	·50	s. 0	·50		·30		·30	
400	·59		·75		·40		·50	
500	·70	0	1·00	0	·45	·10	·60	·10
600	·75		1·00		·60		·70	
700	·85	·15	1·125	·25	·70		·80	
800	1·00		1·150		·70		·90	
900	1·20	R. S. ·20	1·25	·20	·90	·10	1·00	·20
1000	1·40		1·30		·90		1 20	
1100	1·60	30	1·40	·30	·90	s.	1·30	..
1200			1·50		1·25		1·50	s.
1300			1·50	·30	3·55	R.S. 2·00	1 50	·30
1400			1·60				1·90	
1500	7·35		1·60	·40			2 00	
1600	8·85		1·95	R. S.			2·20	
1700	11·80		2·55	·90			2·30	·30
1800	15·50		3·10				2·50	
1900	19·40		4·15				Broke in putting on 1900 lbs.	
2000			5·60	3·00				

"The strength of puddled steel in resisting torsion will be best understood by a direct comparison between the results in the Table (IV.) and those obtained by Major Wade on samples of the same form and

dimensions in cast and wrought iron. The following Table (V.) is an abstract of such of his experiments as afford a direct comparison. In both sets of experiments the weight was applied at the end of a lever 25 inches long.

TABLE V.—*Table showing certain Results obtained by Major Wade on the Torsional Resistance of Cast and Wrought Iron.*

Description.	Weight applied, 1000 lbs.		Weight applied, 1500 lbs.		Remarks.
	Deflection.	Permanent set	Deflection.	Permanent set.	
	°	°	°	°	
CAST IRON:—					
No. 1, 2d fusion,	2·2	0·2	5·9	2·2	Mean of four exper'ts.
" 3d "	1·7	0·0	3·0	0·3	One experiment.
10 parts No. 1 and 4 parts No. 3, 2d fusion,	1·5	0·0	2·4	0·1	"
8 parts No. 1 and 6 parts No. 3, 3d fusion,	1·5	0·0	2·3	0·1	"
Equal parts Nos. 1 and 2, 2d fusion,	1·9	0·1	3·8	0·9	Mean of two exper'ts.
" 3d "	1·2	0·0	2·4	0·0	One experiment.
Mixture of 3 parts No. 1, 3 parts No. 2, and 2 parts No. 3, 2d fusion,	1·4	0·0	2·5	0·1	Mean of four exper'ts.
Mixture of 3 parts No. 1, 3 parts No. 2, and 2 parts No. 3, 3d fusion,	1·6	0·1	2·5	0·2	" "
WROUGHT IRON:—No. 1,		0·0	17·5	16·1	One experiment.
" No. 2,		0·1	10·6	15·4	"
" No. 3,		1·2	39·7	37·7	"

"Good puddled steel and homogeneous metal appear to be very similar in their mechanical properties; their tensile strength being nearly double that of wrought iron, the fracture being without fibre, and possessing a fine crystalline or granular appearance. Both materials are ductile, and may be condensed and consolidated under the hammer. Both materials also, although bending under transverse strain as much as wrought iron with equal weights, are capable of bearing nearly twice as much strain as wrought iron before producing a greater amount of permanent set.

"It is to be regretted that the testing machine in her Majesty's Arsenal at Woolwich is not adapted to receive bars of sufficient length for determining the modulus of elasticity. The very short length of the samples which the machine is capable of receiving in applying tensile and compressive strains, renders it impossible to arrive at correct conclusions from them in respect of the amount of extension and compression per ton per inch."

Mr. Barlow's experiments are an important contribution to our knowledge of puddled steel and the other materials tested. The ultimate strength under tension appears more uniform than might have been anticipated, which speaks well for the skill of the makers. We hope that, having gone thus far, Mr. Barlow may, on some future occasion, be enabled to ascertain by experiment the modulus of elasticity, and other data which still remain undetermined.

Method for Determining the amount of Sulphur in Pyrites.

From Newton's London Journal, Jan., 1862.

Dr. Crace Calvert stated, that he wished to draw the attention of the manufacturing chemists of this district to a very simple and rapid method which had been devised by the eminent chemist, M. Pelouze,

Master of the Paris Mint, for determining the amount of sulphur existing in pyrites. He (Dr. Calvert) was induced to do so, believing that any process which would simplify the long and troublesome operations now followed to ascertain the value of this mineral would be useful to many members now present at this meeting. The process consists in mixing intimately together one part of pyrites, thoroughly pulverized in an agate mortar, with five parts of carbonate of soda, seven parts of chlorate of potass, and five parts of chloride of sodium, and placing the whole in an iron spoon, which is gradually carried to a dull red heat. The mass, when cold, is first washed with cold water and then with boiling water, until the whole of the soluble matter is removed; and this solution is tested with a standard solution of sulphuric acid. As 100 grains of carbonate of soda requires 92·45 of monohydrated sulphuric acid, or $S O_3 H O$, it follows, that the quantity of soda in the carbonate of soda employed, will decrease in proportion to the quantity of sulphur from the pyrites converted into sulphuric acid, which will have neutralized a corresponding quantity of the soda in the carbonate.

This mode of assaying is so simple, that the author states that he can determine, within 1 or $1\frac{1}{2}$ per cent., the value of a sample of pyrites, in the space of an hour's time.

M. Pelouze also states, that by employing the following proportions of the same materials, the manufacturer can determine the amount of sulphur in burnt pyrites:—5 parts of the latter substance are mixed intimately with 5 parts of pure carbonate of soda, and 5 parts of chlorate of potash.

Proceedings Manchester Philosophical Society, Nov. 12, 1861.

Experiments on the Tensile Strength of Gun Metal. By WILLIAM FAIRBAIRN.

From the Lond. Mechanics' Magazine, October, 1861.

SIR—By the kind permission of Mr. Fairbairn, I am enabled to lay before the public the result of some experiments made by that gentleman upon the tensile strength of our gun metal, prepared from various descriptions of British iron. These experiments indicate that the Forest of Dean iron still retains its character of pre-eminent excellence beyond that of any other brand manufactured in the kingdom. The highest tensile strain has been obtained when No. 1 Cinderford grey pig iron was employed in the manufacture of the gun metal. This iron is manufactured at the Cinderford Iron Works, Forest of Dean, by Messrs. Allaway and Crawshay. ROBERT MUSHET.

COLEFORD, Oct. 7, 1861.

—

MANCHESTER, Sept. 13, 1861.

R. MUSHET, Esq.,

DEAR SIR—An opportunity has at length occurred of testing the specimens of gun metal which you forwarded some months ago. The results show an exceedingly high, indeed almost unprecedented, tena-

city. The whole of the specimens were reduced for a length of about 6 inches, to a diameter of 0·625 inches, or to a sectional area of 0·3068 square inches. Thus prepared, without having been heated or forged, they were placed in shackles, and their tensile strength ascertained by dead pressure.

Mark on Bar.	No.	Weight laid on in lbs.	Weight per square inch of section.		Elongation per unit of length.
			lbs.	tons.	
8	1	19·150			·000
	2	27·550			·020
	3	35·950			·037
	4	42·670	139·080	62·100	·078 broke.
5 B	1	19·150			·000
	2	27·550			·012
	3	35·950			·025
	4	44·350			·052
	5	45·865	149·490	66·738	·054 broke.
5 A	1	19·150			·002
	2	27 550			·007
	3	35 950			·019
	4	44 350			·030
	5	49 225	160·540	71·671	·030 broke.
D	1	19·150			·002
	2	27·550			·012
	3	35·950			·027
	4	40·990	133·610	59·645	·037 broke.
M	1	19·150			·005
	2	27·550			·015
	3	35·950	117·180	52·311	·021 broke.
N	1	19·150			·002
	2	27·550			·012
	3	35·950			·040
	4	41·380	136·340	60·867	·055 broke.
P	1	27·550			·019
	2	35·950			·040
	3	39 310	128·130	57·201	·126 broke.
R	1	19·150			·000
	2	27·550			·032
	3	33·430	108 970	48·645	·190 broke.
U	1	19·150			·003
	2	27·550			·015
	3	35·950			·030
	4	44·350	144·560	64·535	·077 broke.
4 Z	1	27·550			·007
	2	39·130			·022
	3	44·350			·032
	4	47·710	155·510	69·424	·055 broke.

Placing these results together in one table, we get the following summary:—

Iron.	Mark on Bar.	Breaking Weight per square inch.		Elongation per unit of length.
		lbs.	tons.	
	8	139·080	62·100	·078
Cleator, No. 2, .	5 B	149·490	66·738	·054
Cinderford, No. 1, .	5 A	160 540	71·671	·030
	D	133 610	59 645	·035
	M	117·180	52 311	·021
	N	136·340	60·867	·055
Swede iron, . .	P	128·130	57·201	·126
Old Park iron, .	R	108 970	48·645	·190
Cleator, No. 3, . .	U	144·560	64·535	·077
Cleator, No. 1, .	4 Z	155·510	69 424	·055
Mean, . .			61·314	·072

The metal indicated by its fracture that the structure of the various bars was different, in some approaching the bright granular fracture of steel, and the others being more iron grained, although the grain was very fine. The steely bars elongated least, and, generally, the bars having the highest tenacity, elongated least; but this rule is not without exceptions.

Rapid Transmission of Telegraphic Signals.

From the Lond. Mechanics' Magazine, October, 1861.

M. Guillemin has recently made some experiments at Paris with a Morse telegraph, similar to that shown at Manchester as M. Siemen's, to ascertain the greatest number of elementary signals (points and dashes), and consequently of words, that can be transmitted per minute over a single line of from 300 to 1000 kilometers in length. M. Guillemin employed, as manipulator, a small automatic transmitter, formed of four brass wheels, 25 centimeters in circumference, and carried upon the same axis. One small wheel produced the dots, another the dashes, and the two others discharged the wire after each signal. The plates which established the communications were wedge-shaped; four springs pressed the surface of the wheels, and the duration of their contact varied for the same uniform rapidity of rotation according as they were pushed from the broad sides towards the small sides of these trapezoidal plates. By this arrangement, the relation between the duration of the contact and the time which intervened between the successive contacts, was modified at pleasure. The transmitter carried only two words, France, Paris, which, in the Morse alphabet, are of about the medium length of French words. These two words were transmitted 30 times in a minute over a line of 570 kilometers in length, in fine weather. During a heavy rain, 40 words were easily transmitted per minute. Between Paris and Nancy, from

60 to 70 words were sent per minute. Over a line of 450 kilometers (the Havre line), words were sent at the rate of 75 per minute. This is about six times more rapid than is common among operators, who generally transmit from 10 to 15 words per minute. When only dots were sent, from 35 to 40 could be transmitted per second, which is at the rate of from 2100 to 2400 separate signals per minute.

For a single wire, the ratio of the duration of contacts to intervals which gives the most rapid transmission, varies according to the insulation of the line; it diminishes when the insulation is good, and increases when the escape is large. As this ratio, by means of M. Guillemin's apparatus, may be varied at pleasure, a great rapidity of transmission can always be attained. When the wire is well insulated, it is necessary to use wheels, which, after each discharge of the current, are placed in communication with the earth by the extremity which has touched the pile; without this precaution, all the elementary signals join together before a speed of 50 words per minute is attained. In certain cases, there is even an advantage in hastening the discharge of the wire, by means of a weak current in the opposite direction to that in which the signal is sent. When the insulation is defective, the discharging wheels are useless; but signals are sent less surely and less rapidly than in the first case. Besides, it is not necessary to discharge completely the wire between two elementary signals; that may even be injurious to the rapidity of transmission. It is necessary only to produce sensible variations in the intensity of the current which moves the electro-magnet of the receiver.

In conclusion, M. Guillemin states that great rapidity in the transmission of signals can only be obtained by means of an automatic manipulator, arranged so as to permit the operator to vary at pleasure the duration of the contacts, and the intervals which separate them, and so as to favor the discharge from the wire within proper limits.

Schneider's Electric Sounding Apparatus.

From the Lond. Mechanics' Mag., October, 1861.

It is stated in *Le Recueil Maritimé*, that experiments were made on the Lake Ladoga on June 11th, with Schneider's Electric Sounding Apparatus. The Russian steamer *Ladoga* has lately been employed in taking soundings in the lake of the same name, and M. Schneider was invited by the Russian Minister of Marine to test his invention. His apparatus consists of an electric battery using six elements. The sounding line was gutta-percha, (300 sajenes) 1800 feet in length, 2 lines in thickness, and covered. It contained two wires, one inside the gutta-percha, and one inside the outer covering. Bruck's sounding apparatus, slightly modified, was used. The weight of the leaden plummet was 12 lbs., but no portion of it was detached by contact with the bottom, as in Bruck's. The experiment commenced 6 miles east of the island of Valaam, and soundings were taken at different depths, varying from 156 ft. to 660 ft., and in each case both Bruck's sounding apparatus and Schneider's were used. At the moment the

latter touched the ground, the alarm clock attached to the apparatus was sounded by the electric current. Thirty-four soundings were made altogether, and in each case with the same results; the moment the plummet reached the bottom, although it was soft or muddy, the electric current sounded the alarm. The steamer *Ladoga* being of iron, M. Schneider made some experiments with only one of the wires, viz: that contained in the gutta-percha, thus making the iron vessel the upper metallic plate, and the sounding apparatus the lower metallic plate. The result was so satisfactory that a smaller and lighter line may be used, containing only one wire. After the experiments, M. Schneider's line was found to have lengthened 1 foot in 600, while the ordinary line was 4½ feet in 600 longer. M. Schneider's apparatus is said to be cheap and easily managed, and likely to be useful for deep-sea soundings.

For the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillars: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By Wm. Bryson, Civ. Eng.

(Continued from page 189.)

Solid Cylindrical Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Cubical content in feet.	Approximate weight of pillar in lbs.	Calculated breaking weight in tons from formulæ, $W = 6{\cdot}71\frac{D^4}{L^2}$ $Y = \frac{W c}{W + \frac{1}{2} c}$.
8	8	12	2·792	131·73	133·13
9	"	13·5	3·141	148·20	125·38
10	"	15	3·490	164·67	117·73
11	"	16·5	3·839	181·13	110·29
12	"	18	4·188	197·60	103·15
13	"	19·5	4·537	214·07	96·36
14	"	21	4·886	230·53	89·98
15	"	22·5	5·235	247·00	83·99
16	"	24	5·584	263·47	78·42
17	"	25·5	5·934	279·93	73·25

Solid Cylindrical Pillars of Red Deal, Both Ends being Flat and Firmly Fixed.

					$W = 4{\cdot}79\frac{D^4}{L^2}$ $Y = \frac{W c}{W + \frac{1}{2} c}$.
8	8	12	2·792	121·60	108·53
9	"	13·5	3·141	136·80	101·38
10	"	15	3·490	152·00	94·43
11	"	16·5	3·839	167·20	87·77
12	"	18	4·188	182·40	81·44
13	"	19·5	4·537	197·60	75·60
14	"	21	4·886	212·80	70·13
15	"	22·5	5·235	228·00	65·06
16	"	24	5·584	243·20	60·41
17	"	25·5	5·934	258·40	56·13

In Appleton's Dictionary of Mechanics, &c., vol. ii., p. 620, the following practical formula is given, by which to determine the amount of weight a solid cylindrical oak column will support, in lbs.:—

$$\frac{2470\,d^4}{4\,d^2 + \cdot 5\,l^2} = \text{W}.$$

Table showing the Weight Cylindrical Pillars of Oak will support, in lbs. and tons, deduced from the above formula.

Diam'ter in inches	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	1,162	823	598	449				
3	3,705	2,942	2,326	1,852				
4	7,711	6,586	5,546	4,649	3,903	3,293		
5	13,082	11,695	10,291	8,975	7,796	6,770	5,892	5.145
6	19,760	18,188	16,500	14,820	13,227	11,768	10,461	9,305
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	0·51	0·36	0·26	0·20				
3	1·65	1·31	1·03	0·82				
4	3·44	2·94	2·47	2·07	1·74	1·47		
5	5·84	5·22	4·59	4·00	3·48	3·02	2·63	2·29
6	8·82	8·11	7·36	6·61	5·90	5·25	4·67	4·15

Table showing the Weight that may be safely borne by Solid Cylindrical Pillars of Oak, deduced from Mr. Haswell's formula, in lbs. and tons,

$$\frac{2500\,d^4}{4\,d^2 + \cdot 5\,l^2} = \text{W}.$$

Diameter in inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	1,176	833	606	454				
3	3,750	2,977	2,354	1,875				
4	7,804	6,666	5,614	4,705	3,950	3,333		
5	13,241	11,837	10,416	9,084	7,891	6,853	5,963	5,208
6	20,000	18,409	16,701	15,000	13,388	11,911	10,588	9,418
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	0·52	0·37	0 27	0 20				
3	1·67	1·32	1·05	0·82				
4	3 48	2·97	2·50	2·10	1·76	1·48		
5	5·91	5·28	4 65	4·05	3·52	3·05	2·66	2·32
6	8·92	8·21	7·45	6·69	5·97	5 31	4·72	4·20

Table showing the Weight that Solid Cylindrical Pillars of English Oak will sustain with Safety, deduced from Mr. Tredgold's formula, in lbs. and tons,

$$\frac{2470\,d^4}{d^2 + \cdot 5\,l^2} = \text{W}.$$

Diameter in inches	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	1,796	1,097	731	520				
3	7,410	4,879	3,391	2,470				
4	18,597	13,173	9,580	7,185	5,546	4,391		
5	35,901	27,083	20,583	15,914	12,550	10,089	8,255	6,861
6	59,280	47,075	37,222	29,640	23,888	19,519	16,167	13,564
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	0·80	0·48	0·32	0·23				
3	3·30	2·17	1·51	1·10				
4	8·30	5 88	4·27	3·20	2·47	1·96		
5	16·02	12·09	9·18	7·10	5·60	4·50	3·68	3·06
6	26·46	21·01	16·61	13·23	10·66	8·71	7·21	6 05

Tables showing One-Tenth and One-Fourth of the Calculated Breaking Weight of Solid Cylindrical Pillars of Dantzic Oak, in Tons, as deduced from my calculations, given in preceding tables.

Table showing One-Tenth of the Breaking Weight.

Diameter in Inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	0·29	0·16	0·10	0 07				
3	1·10	0·77	0 54	0·37				
4	2·57	1·96	1·49	1·16	0·87	0·67		
5	4·71	3·81	3·06	2·46	2·00	1·63	1·29	1·04
6	7 48	6·34	5·29	4·41	3·68	3·09	2·61	2·17

Table showing One-Fourth of the Breaking Weight.

2	0·72	0·41	0·26	0·18				
3	2·75	1·93	1·35	0·94				
4	6·44	4·90	3·74	2·90	2·19	1·67		
5	11·79	9·53	7·65	6·17	5·01	4·09	3·23	2·62
6	18·71	15·85	13·24	11·02	9·20	7·73	6·54	5·43

In the *Journal of the Franklin Institute*, vol. xli., pp. 246 and 247, Mr. Haswell gives the following. "To ascertain the Crushing Strength of a Solid Cylindrical Column of Cast Iron, $\frac{d^{3.6}}{l^{1.7}} \times 100{,}000 = w$. d representing the diameter of the column in inches, l, its length in feet, and w, the crushing weight.

"To ascertain the Crushing Strength of a Hollow Cylindrical Column of Cast Iron, $\frac{D^{3.6} - d^{3.6}}{l^{1.7}} \times 100{,}000 = w$. D representing the greater diameter.

"The above formulæ are those of Hodgkinson for the breaking or crushing weight. The formulæ of Euler, which are for the incipient breaking weight, are preferable, and are, with the alteration of the co-efficient, thus: $\frac{d^4}{l^2} \times 100{,}000 = w$, for solid cylinders, and $\frac{D^4 - d^4}{l^2} \times 100{,}000 = w$, for hollow cylinders.

"The above formulæ apply to all columns where the length is not less than about 30 times the external diameter."

One of the earliest writers on the strength of pillars was Euler. He published, first in Berlin Memoirs for 1757, and confirmed in the Petersburgh Commentaries for 1778, his theory that the strength of prismatic pillars is in the direct quadruplicate ratio of their diameters, and the inverse ratio of their lengths. His investigations were followed out by Poisson, who states, in his "*Mecanique*," that the formula for the strength of a cylindrical column is of this form: Resistance varies as $\frac{d^4}{l^2}$, where d is the diameter of the column, and l, its length.

Professor Moseley remarks, "For all the knowledge on this subject [the strength of pillars] on which any reliance can be placed by the engineer, he is indebted to experiment."

"The hypothesis upon which it has been customary to found the theoretical discussion of it, is obviously insufficient; and the results have been shown by Mr. Hodgkinson to be so little in accordance with those of practice, that the high sanction it has received from labors such as those of Euler, Lagrange, Poisson, and Navier, can no longer establish for it a claim to be admitted among the conclusions of science."

Table showing the Incipient Breaking Weight of Solid Cylindrical Pillars of Cast Iron, deduced from Mr. Haswell's formula, in lbs. and tons,

$$\frac{d^4}{l^2} \times 100{,}000 = \text{w}.$$

Diameter in inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	44,000	25,000	16,000	11,111	8,163	6,250	4,938	4,000
3		126,562	80,000	56,250	41,326	31,640	25,000	20,250
4				177,777	130,612	100,000	79,012	64,000
5					318,877	244,140	192,901	156,250
6						506,250	400,000	324,000
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	19·64	11·16	7·14	4·96	3·64	2 79	2 20	1·78
3		56·50	35·71	25·11	18 44	14·12	11·16	9·04
4				79 36	58·30	44·64	35 27	28 57
5					142·35	108·99	86 11	69 75
6						226·00	178·57	144·64

Table showing the Breaking Weight of Solid Cylindrical Pillars of Cast Iron, deduced from Mr. Haswell's formula, in lbs. and tons,

$$\frac{d^{3.6}}{l^{1.7}} \times 100{,}000 = \text{w}.$$

Diameter in inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	57,652	35,352	24,192	17,745	13,654	10 881	8,901	7,445
3		152,188	104,144	76,389	58,778	46,841	38,342	32 053
4				215,179	165,572	131,948	108,007	90,291
5					369,725	294,642	241,181	201,621
6						567,988	464,930	388,669
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	25·73	15·78	10·80	7 92	6·09	4 85	3·97	3 32
3		67·94	46·49	34·10	26 24	20·91	17·11	14·30
4				96 06	73·91	58·90	48·21	40·30
5					165 05	131·53	107·67	90 00
6						253·56	207·55	173·51

Table showing the Breaking Weight of Solid Cylindrical Pillars of Cast Iron, deduced from Mr. Hodgkinson's formula, in tons (applicable to pillars exceeding 24 diameters, as shown in preceding tables, and as below),

$$\text{w} = 44{\cdot}16\,\frac{\text{D}^{3.55}}{\text{L}^{1.7}}.$$

Diameter in inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	24·58	15·07	10 31	7 56	5·82	4·64	3·79	3·17
3		63·60	43·52	31 92	24·56	19·57	16·02	13·39
4			120·87	88 66	68 22	54·36	44·50	37·20
5				195 77	150·64	120·05	98·26	82·15
6					287·76	229·32	187·71	156 93

Abstract from Mr. Tredgold's table, entitled

"*A Table to show the Weight or Pressure a Cylindrical Pillar or Column of Cast Iron will Sustain with Safety, in hundredweights.*"

Diameter in inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.
2	60	49	40	32	26	22	18	15
2½	105	91	77	65	55	47	40	34
3	163	145	128	111	97	84	73	64
3½	232	214	191	172	156	135	119	106
4	310	288	266	242	220	198	178	160
4½	400	379	354	327	301	275	251	229
6	592	573	550	525	497	469	440	413

Table showing the calculated weight from Mr. Tredgold's formula, in cwts. and tons,

$$\frac{9562\,d^4}{4\,d^2 + 18\,l^2} = \text{w.}$$

Diameter in inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
2	60·75	49·63	40·16	32·58	26·63	22·00	18 37	15·51
2½	105 93	91·31	77·55	65·49	55 32	46·91	40·01	34·37
3	162·78	145·51	128·06	111·67	97·00	84·25	73·31	64·02
3½	230·91	211·68	191·21	171·00	152 00	134 74	119 40	105·87
4	310·09	289·40	266 53	243 05	220·14	198 54	178·67	160·71
4½	400·18	378 39	353 62	327·42	301·07	275·48	251·27	228·81
5½	612·82	589·51	562 03	531·74	499·89	467·58	435·66	404·77
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	3·03	2·48	2·00	1·62	1·33	1·10	0·91	0·77
2½	5 29	4·56	3·87	3 27	2·76	2 34	2·00	1 71
3	8·13	7·27	6 40	5 58	4·85	4 21	3 66	3·20
3½	11·54	10 58	9 56	8·55	7 60	6·73	5·97	5 29
4	15·50	14·47	13·32	12·15	11·00	9·92	8·93	8 03
4½	20·00	18·91	17·68	16·37	15·05	13·77	12 56	11·44
5½	30·64	29·47	28·10	26·58	24·99	23·37	21·78	20·23

Abstract from Mr. Haswell's table, entitled

"*Table showing the Weight or Pressure a Column of Cast Iron will Sustain with Safety.*"

	Length or height in Feet.							
	6	8	10	12	14	16	18	20
Inch.								
2·5	12,285	10,647	9,009	7,605	6,435	5,499	4,680	3,978
3	19,071	16,965	14,976	12,987	11,349	9,828	8,541	7,488
3·5	27,144	25,038	22,347	20,124	18,252	15,975	13,923	12,402
4	36,270	33,696	31,122	28,314	25,740	23,166	20,826	18,720
4·5	46,800	44,343	41,418	38,259	35,217	32,175	29,367	26,793
6	69,264	67,041	64,350	61,425	58,149	54,873	51,480	48,321

Table showing the calculated weight from Mr. Haswell's formula, in pounds and tons,

$$\frac{10{,}000\,d^4}{4\,d^2 + \cdot 18\,l^2} = \text{W}.$$

Diameter in inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	7,117	5,813	4,705	3,816	3,120	2,577	2,152	1,818
2·5	12,408	10,696	9,084	7,671	6,480	5,495	4,688	4,027
3	19,067	17.045	15 000	13,081	11,363	9,868	8,587	7,500
3·5	27,048	24,795	22,397	20,029	17.805	15,782	13,982	12,401
4	36,322	33.898	31,219	28.469	25,785	23,255	20,928	18,823
4·5	46.875	44,321	41,420	38,352	35 265	32,268	29,433	26,801
5·5	71,780	69,050	65,831	62,283	58,552	54 767	51,029	47,412
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	3 17	2·59	2·10	1 70	1 39	1·15	0·96	0 81
2·5	5·53	4·77	4·05	3·42	2·89	2·45	2·09	1·79
3	8·51	7·60	6 69	5 83	5·07	4·40	3 83	3 34
3·5	12·07	11·06	9·99	8 94	7·94	7·04	6·24	5·53
4	16 21	15·13	13·93	12·70	11 51	10·38	9·34	8 40
4 5	20·92	19·78	18·49	17·12	15·74	14·40	13·13	11 96
5 5	32·04	30 82	29·38	27·80	26 13	24 44	22·77	21·16

Table showing One-Tenth of the Calculated Breaking Weight, in Tons, as deduced from Mr. Hodgkinson's formulæ for Cast Iron Solid Pillars with Flat Ends.

Diameter in inches.	Length or height in Feet.							
	6	8	10	12	14	16	18	20
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	2·45	1·50	1·03	0·75	0·58	0 46	0 37	0·31
2½	5 43	3 33	2·27	1·67	1·28	1·02	0·83	0 70
3	9 88	6·36	4·35	3·19	2 45	1·95	1·60	1·33
3½	15·86	10·99	7 52	5·51	4·24	3 38	2·77	2 31
4	23·65	17·03	12·08	8·86	6·82	5 43	4 45	3·72
4½	33·36	24·52	18·36	13·46	10·36	8 25	6·76	5·65
5½	58·83	44·84	34 93	27·46	21·12	16·83	13·78	11·52

Table showing One-Fourth of the Calculated Breaking Weight, in Tons, as deduced from Mr. Hodgkinson's formulæ for Cast Iron Solid Pillars with Rounded Ends.

2	2·39	1·47	1·00	0·73	0·56	0·45	0·37	0·30
2½	5 54	3·40	2 32	1 70	1·31	1·04	0·85	0·71
3	11·02	6 75	4·62	3·39	2·60	2·07	1·70	1·42
3½	19·67	12·06	8·25	6·05	4·66	3·71	3·04	2 54
4	32·50	19·93	13 64	10·00	7·69	6·13	5·02	4·19
4½	50·12	31·04	21·24	15·58	11·98	9 55	7 82	6·53
5½	96·12	66·01	45·17	33·13	25·49	20·31	16·63	13·90

Table showing One-Fourth of the Calculated Breaking Weight, in Tons, as deduced from Mr. Hodgkinson's formulæ for Cast Iron Solid Pillars with Flat Ends.

2	6·14	3·76	2 57	1·89	1·45	1·16	0 94	0·79
2½	13·58	8·32	5 69	4·17	3·21	2·56	2·09	1·75
3	24·70	15·90	10·88	7·98	6·14	4 89	4·00	3·34
3½	39·65	27·48	18·81	13 79	10·61	8·46	6·92	5·78
4	59·13	42·58	30·21	22·16	17·05	13 59	11·12	9·30
4½	83·41	61·30	45·90	33 67	25 90	20 64	16·90	14·12
5½	147·09	112·11	87·34	68 65	52 82	42 09	34·45	28·80

Table comparing the Strength of Solid Uniform Cylindrical Pillars of Cast Iron, having Both Ends Rounded or Irregularly Fixed, with Pillars of the same dimensions, having Both Ends Flat and Firmly Fixed: deduced from Mr. Hodgkinson's formulæ as given in preceding tables.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Rounded Ends or Irregularly Fixed.			Flat Ends and Firmly Fixed.			Mean ratio of strength.
			Calculated breaking weight per sq. inch in tons from the index		Mean strength per sq. inch in tons.	Calculated breaking weight per sq. inch in tons from the index		Mean strength per sq. inch in tons.	
			3·6.	3·76.		3·55.	3·6.		
2	2	12	15 92	17·13	16·52	28 39	28 81	28·60	1·73
3	"	18	8·88	9·92	9·40	20·03	20 44	20·23	2·15
4	"	24	5·44	6·08	5 76	14·59	14 95	14·77	2·56
5	"	30	3·72	4·16	3 94	10 66	11·04	10 85	2·75
8	"	48	1·67	1·87	1·77	4·79	4 96	4·87	2·75
14	"	84	0 64	0 72	0·68	1·85	1·91	1 88	2·76
20	"	120	0·35	0·39	0 37	1 00	1 04	1 02	2·75
2	3	8	23·49	25 65	24 57	35·33	35 86	35·59	1·44
3	"	12	15·49	17·41	16·45	27·67	28·33	28·00	1·70
4	"	16	10·42	12 37	11 39	21·71	22·37	22·04	1 93
5	"	20	7·13	8 50	7·81	17·27	17·89	17·58	2 25
8	"	32	3·20	3 82	3·51	8 99	9 50	9·24	2 63
14	"	56	1 23	1·47	1·35	3·47	3 67	3 57	2 64
20	"	80	0·67	0 80	0·73	1 89	2 00	1·94	2 65
2	4	6	29 08	31 63	30·35	39 27	39 80	39·53	1·29
4	"	12	15·19	17 60	16·39	27 07	27 98	27·52	1·67
6	"	18	8 28	10·34	9·31	18 82	19 63	19·22	2·06
8	"	24	5 08	6·34	5 71	13 55	14 24	13·89	2 43
10	"	30	3 47	4·34	3·90	9 61	10·30	9·95	2 52
14	"	42	1·96	2·45	2·20	5·42	5 81	5 61	2·55
20	"	60	1·07	1·33	1·20	2·96	3·17	3·06	2·55
2	5	4·8	33·12	35·75	34·43	41·69	42·17	41 93	1·21
4	"	9·6	19·16	22 23	20 69	31·22	32·12	31·67	1·53
6	"	14·4	11·84	14·28	13·06	22·95	23·94	23·44	1·79
8	"	19 2	7·26	9·39	8 32	17 19	18·10	17 64	2·12
10	"	24	4·97	6 43	5 70	13 23	14·02	13·62	2·38
12	"	28 8	3·64	4·71	4·17	9·97	10·80	10·38	2·48
14	"	33·6	2·80	3 62	3·21	7·67	8·31	7 99	2 48
16	"	38·4	2·23	2·89	2·56	6·11	6·62	6 36	2 48
18	"	43·2	1·82	2·36	2·09	5·00	5·42	5 21	2·49
20	"	48	1·52	1·97	1·74	4 18	4·53	4·35	2·50
2	6	4	36·08	38·62	37·35	43·28	43·71	43·49	1·16
4	"	8	22·65	26 15	24·40	34·28	35·18	34·73	1·42
6	"	12	14·77	17·88	16 32	26 41	27·49	26 95	1 65
8	"	16	9·72	12·77	11·24	20·46	21·53	20 99	1 86
10	"	20	6·65	8 86	7 75	16·12	17·11	16 61	2·14
12	"	24	4·88	6 50	5 69	12 94	13 84	13·39	2 35
14	"	28	3·75	5·00	4·37	10·17	11·13	10 65	2 43
16	"	32	2·99	3·98	3·48	8 11	8 87	8 49	2 43
18	"	36	2·44	3·26	2·85	6 63	7 26	6·94	2 43
20	"	40	2 04	2 72	2 38	5·55	6·07	5 81	2·44
12	7	20·57	6·24	8·52	7·38	15·37	16 41	15 89	2·15
16	"	27·42	3·83	5 22	4 52	10·29	11·35	10·82	2·39
20	"	34·28	2 62	3·57	3 09	7 04	7·76	7 40	2·39
12	8	18	7·73	10·78	9·25	17·63	18·82	18·22	1 96
16	"	24	4·74	6 61	5 67	12 56	13·55	13·05	2 30
20	"	30	3 24	4·52	3·88	8·66	9·61	9·13	2·35
12	9	16	9·33	13·00	11·16	19·74	21·04	20 39	1 82
16	"	21·33	5·72	8·13	6 92	14·34	15 47	14·90	2·15
20	"	26·66	3·91	5·56	4·73	10 40	11·61	11·00	2 32
16	10	19·2	6·77	9·79	8·28	16 05	17 31	16·68	2 01
20	"	24	4·63	6·70	5·66	12·25	13·33	12·79	2·25
16	11	17·45	7·89	11·58	9·73	17·68	19·06	18·37	1·88
20	"	21·81	5·40	7·92	6·66	13 65	14·86	14·25	2·13
16	12	16	9·07	13·16	11·11	19·23	20·70	19 96	1·79
20	"	20	6·20	9 24	7·72	15 02	16·34	15·68	2·03

The following table shows the strength of hollow uniform cylindrical pillars of cast iron, in ordinary use for mill purposes, warehouses, and other large structures. I have computed the strength by three of Mr. Hodgkinson's formulæ, as given by him for pillars with flat ends and firmly fixed, both for the breaking weight of the pillars, and per square inch of section; also, for similar pillars, having rounded ends or irregularly fixed, by three other of his formulæ.

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight of pillar in tons from formulæ, $W = 44{\cdot}34\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$, $Y = \frac{We}{W + \frac{1}{3}e}$.	$W = 44{\cdot}3\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$, $Y = \frac{We}{W + \frac{1}{3}e}$.	$W = 42{\cdot}347\frac{D^{3{\cdot}5} - d^{3{\cdot}5}}{L^{1{\cdot}68}}$, $Y = \frac{We}{W + \frac{1}{3}e}$.
6	8	6	9	784·94	807·97	777·39
7·5	"	"	11·25	697·52	721·38	693·32
8	"	"	12	670·11	697·86	666·94
9	"	"	13·5	618·28	647·30	617·17
10	"	"	15	570·58	600·28	571·42
10·5	"	"	15·75	548·27	578·14	550·03
11	"	"	16·5	526·97	556·91	529·60
11·5	"	"	17·25	506·65	536·55	510·11
12	"	"	18	487·28	517·07	491·52
12·5	"	"	18·75	468·82	498·44	473·79
14	"	"	21	418·58	447·35	425·44
16	"	"	24	362·14	389·33	370·86
18	"	"	27	315·68	341·04	325·65
20	"	"	30	277·22	300·72	288·00
				$W = 44{\cdot}34\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$.	$W = 44{\cdot}3\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$.	$W = 42{\cdot}347\frac{D^{3{\cdot}5} - d^{3{\cdot}5}}{L^{1{\cdot}68}}$.
22	"	"	33	238·08	266·05	252·37
24	"	"	36	205·35	229·47	219·00
26	"	"	39	179·22	200·28	192·21
28	"	"	42	158·01	176·57	170·34
30	"	"	45	140·52	157·03	152·22
				Calculated breaking weight per square inch of section from the above formulæ, in tons.		
6	8	6	9	35·69	36·74	35·37
7·5	"	"	11·25	31·71	32·93	31·52
8	"	"	12	30·47	31·73	30·32
9	"	"	13·5	28·11	29·43	28·06
10	"	"	15	25·94	27·29	25·97
10·5	"	"	15·75	24·93	26·28	25·01
11	"	"	16·5	23·96	25·32	24·08
11·5	"	"	17·25	23·03	24·39	23·19
12	"	"	18	22·15	23·51	22·35
12·5	"	"	18·75	21·31	22·66	21·54
14	"	"	21	19·03	20·34	19·34
16	"	"	24	16·46	17·70	16·86
18	"	"	27	14·35	15·50	14·80
20	"	"	30	12·60	13·67	13·09
22	"	"	33	10·82	12·09	11·47
24	"	"	36	9·33	10·43	9·95
26	"	"	39	8·14	9·10	8·74
28	"	"	42	7·18	8·16	7·74
30	"	"	45	6·38	7·14	6·92

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Rounded or Irregularly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight of pillar in tons from formulæ, $W = 13\frac{D^{3\cdot6} - d^{3\cdot6}}{L^{1\cdot7}}$ and $Y = \frac{We}{W + \frac{2}{3}e}$.	$W = 13\frac{D^{3\cdot76} - d^{3\cdot76}}{L^{1\cdot7}}$ and $Y = \frac{We}{W + \frac{2}{3}e}$.	$W = 14{\cdot}78\frac{D^{3\cdot6} - d^{3\cdot6}}{L^{1\cdot7}}$ and $Y = \frac{We}{W + \frac{2}{3}e}$.
6	8	6	9	504·25	600·16	538·78
7·5	"	"	11·25	404·88	498·31	437·79
9	"	"	13·5	330·02	416·88	360·11
10·5	"	"	15·75	273·23	352·19	300·22
12	"	"	18		300·62	
				$W = 13\frac{D^{3\cdot6} - d^{3\cdot6}}{L^{1\cdot7}}$.	$W = 13\frac{D^{3\cdot76} - d^{3\cdot76}}{L^{1\cdot7}}$.	$W = 14{\cdot}78\frac{D^{3\cdot6} - d^{3\cdot6}}{L^{1\cdot7}}$.
12	"	"	18	218·79		248·75
14	"	"	21	168·35	240·62	191·40
16	"	"	24	134·16	191·75	152·53
18	"	"	27	109·82	156·96	124·85
20	"	"	30	91·80	131·21	104·37
22	"	"	33	78·07	111·59	88·76
24	"	"	36	67·34	96·25	76·56
26	"	"	39	58·77	84·00	66·82
28	"	"	42	51·81	74·06	58·91
30	"	"	45	46·08	65·86	52·39
				Calculated breaking weight per square inch of section from the above formulæ, in tons.		
6	8	"	9	22·92	27·29	24·49
7·5	"	"	11·25	18·41	22·65	19·90
9	"	"	13·5	15·00	18·95	16·37
10·5	"	"	15·75	12·42	16·01	13·65
12	"	"	18	9·94	13·67	11·31
14	"	"	21	7·65	10·94	8·70
16	"	"	24	6·10	8·71	6·93
18	"	"	27	4·99	7·13	5·67
20	"	"	30	4·17	5·96	4·74
22	"	"	33	3·55	5·07	4·03
24	"	"	36	3·06	4·37	3·48
26	"	"	39	2·67	3·81	3·03
28	"	"	42	2·35	3·36	2·67
30	"	"	45	2·09	2·99	2·38

I have been unable to complete the above table in time for the press for this month's number; it will therefore be given in a future number, along with tables which I have computed for the Strength of Hollow Pillars, similar to those which were employed in the construction of the Pemberton Mill, Lawrence, Mass., and the pillar referred to in evidence before the coroner's jury; and, in connexion with the tables, it may not be out of place to give some extracts, as obtained from various sources.

(To be Continued.)

The Annealing Temperatures of Metals and Crystallization produced by Vibration.

From the Lond. Practical Mechanics' Journal, January, 1862.

Few examples, numerous as these are in all directions, more strongly indicate the intimate and important, although far from superficially obvious, relations, that subsist between the higher physics and the most common and humble practical arts, than do those which concern the molecular properties of the applied metals under the various conditions to which practical uses subject them. Upon two classes of molecular change in metals we propose to offer some remarks, on both of which much remains to be known.

The construction and the safety of the millions of railway wheels that carry men and merchandise over the civilized globe, (with the small exception of the untyred wheels used in North America,) and of all the future ordnance of the world—for towards built-up guns it all assuredly tends—alike depend upon the "shrinking on hot" of one ring of metal over another.

The *amount* of shrinkage, the degree of coercive radial compression produced by the ring or tyre, and the co-ordinate tension suffered by the latter, are all important to be known, or determinable beforehand, and this knowledge demands our acquaintance with certain molecular changes induced in metals (and more especially in iron and steel) by alterations of temperature which, up to the present moment, are almost wholly unknown. The result is, that the "tyreing of wheels" is, we may say, altogether a matter of "rule of thumb," and the shrinking on upon each other of the successive plies of rings of built-up guns, such as "the Armstrong," equally one of "trial and error," and in every individual piece "shrunk on," one of danger and uncertainty in result at the best.

The effects of such empirical practice as respects wheels were rendered terribly apparent during the last severe winter upon nearly all our great lines of railway. The mere dropping of our winter cold a few degrees below the average temperature of our climate produced day after day (and worst of all at night, when the temperature was a minimum) the bursting of innumerable tyres, attended with loss of life and property, and with obstructed railways, until at length the danger became so great that the speed even of our mail trains was, with the consent of government, temporarily reduced upon most of our great lines of communication.

Another winter has come, which possibly may be as severe, yet our engine and carriage, and truck wheels, remain just as they were, with the exception of some inventions, patent or otherwise, proposing to "get into the rere" of the difficulty by abandoning shrunk on tyres altogether, a thing not likely for general adoption—in fact, impossible to be adopted at once, if ever so perfect, and leaving out of view the huge existing stock of wheels that must be worn out, safe or unsafe.

Nothing has been done in the only true direction, namely, that

which shall enable us to know what we are about when we "shrink on a tyre."

We are not now going to write either about the constructive form or parts of wheels or detail of railway wheel making, still less about "building up" cannon; but we mean to offer some remarks upon what lies at the foundation of both, coupled also with some upon a closely allied set of molecular conditions, upon which the safety and durability in service, both of wheels and of guns, has been assumed greatly to depend. Our object is to direct the attention of our physical philosophers and educated engineers to our ignorance, and, while we ask these "light bearers" to illuminate us practical men in the directions in which we want light, to suggest, in part, the means by which science may hope to attain it.

When a cylindric iron ring, like a wheel tyre or gun segment, which just fits a solid cylinder on which it is placed, is reduced in temperature, and, therefore, diminished in length, it has been long assumed by writers on physics that, for each depression of 15° of Fahrenheit's scale nearly, a diminution of length will take place equal to about $\frac{1}{10000}$ of its length; and as the extension of a bar of wrought iron of mean quality is about the same, when extended by a force equivalent to one ton per square inch, so the tangential tension or grip of the ring is said to equal a ton per inch of section for each 15° Fahrenheit lowering of temperature.

This is, *in no case, strictly true*, though, within the limits of a few hundred degrees above or below a temperate atmosphere (say 50 Fah.), it may approximate to fact.

At much higher temperatures, however, what happens? Take the case of a railway tyre shrunk on the wheel it has been fitted to, at some temperature between black redness and bright redness. Here two new phenomena come into play. The metal, heated until its molecular condition is altered, and more or less of its rigidity gone, and replaced by a new state of ductility and softness, amounting in the higher extremes almost to plasticity, *is no longer in a condition to transmit the force* of its own contraction, and the latter is expended, not in laboring force at any point of the circumference, but in work done within the particles of the bar, in altering its form and *increasing* its length permanently, and the final effort of the lost heat, expended in "grip," is only the *residual strain*, or difference between the total force of contraction due to the entire heat laid up in the applied ring, and that already expended in permanent alteration of form. The ratio between these two portions of the total force of the heat varies, as the ring is shrunk on at a lower or higher temperature, in virtue of the facts chiefly ascertained by the Franklin Institute, bearing upon the loss of ultimate passive resistance to tension, produced in iron by continuous elevation of temperature. Thus, at 900° Fahrenheit, the resistance to tension is reduced in round numbers $\frac{1}{4}$th, at 1050° $\frac{1}{2}$, at 1240° $\frac{3}{4}$ds, at 1317° $\frac{7}{10}$ths, and at 3945° Fahrenheit, the fusing point, it of course becomes zero. So that, if we take the average resistance to rupture at common temperatures of a wheel tyre to be 24 tons to

the inch of section, and shrink it on at different higher temperatures, the succeeding table will show the proportion in which the total force of contraction is divided between grip and elongation of the ring.

Temperature.	As known by workmen.	Effort of Contraction per square inch.	Effort of Elongation per square inch.
900° Fah.	Black Red.	18 tons.	6 tons.
1050° "	Low Red.	12 "	12 "
1240° "	Bright Red.	8 "	16 "
1317° "	Yellow.	7 "	17 "
3945° "	White.	0 "	0 "

It follows that, *cæteris paribus*, the grip depends not only upon the lowest temperature to which the ring is exposed, but also upon the highest temperature at which it is shrunk on. But, besides the continual though not equable reductions in tenacity due to increase of temperature, another molecular condition comes into play, in "shrinking on hot," which, at a certain though unknown point of elevation, produces an abrupt, permanent, and often large reduction in the tensile strength of the iron, as well as alteration in the preceding relations.

At a determinate, though as yet undetermined temperature, the iron becomes *annealed*. The arrangement of its particles, as induced by rolling, &c. (to still confine ourselves to the illustration of the tyre) is altered again when heated to a *certain* point; their relative distances are increased, as evidenced by diminished specific gravity, and the tensile strength at the same moment greatly decreased. Salient examples of this are familiar in brass or steel pianoforte wire: as these come hard and elastic from the draw plate, the former has a tensile resistance of 87,000 lbs. per square inch (nearly that of wrought iron), and the latter of 120,000 lbs. per square inch, or even more. In this state either metallic wire coiled round a cylinder (such as one of the wire-wrapped guns proposed by Mr. Longridge) would transmit in "grip" very nearly the whole tension due to its reduction in length for each thermometric degree. But let the brass wire be heated to something above a red heat in daylight, and the steel wire to a still more elevated temperature (a yellow heat in daylight at the very least), and the ultimate tenacity of each is found enormously and suddenly reduced. The brass wire will now tear asunder at 17,000 or 18,000 lbs. per square inch, and the steel at 70,000 to 80,000. Both, however, elongate greatly more than before, so that it is probable that the co-efficient (*of Poncelet*), that is to say, *the foot pounds expended in the work of rupture*, is the same before and after annealing; but inasmuch as the "grip" in any given case greatly depends upon the relation between the range of elongation by tension, and the final resistance to rupture—in other words, upon the ratio between the two factors, of which the above co-efficient is made up, so without a knowledge of the precise temperature at which this sudden molecular change

called annealing takes place, our operations of shrinking on must, in this second respect, remain but tentative and unsatisfactory.

Now the fact is, that the "annealing temperature" has not been yet ascertained for any one metal, and all that is known about it is, that there is a fixed and rather narrow range of elevated temperature peculiar to each metal, without the limits of which, annealing does not take place, and that the absolute mean temperature for each metal seems to be greater in some proportion as the fusing temperature of the metal itself is higher. Platina, for instance, when hard from wire-drawing or lamination, is not annealed under an intense white heat; wrought iron at about a bright red; in some sorts, not before a yellow heat; copper, at a low cherry red; and when we come down to the metals of very ready fusibility, such as tin and lead, their annealing temperature appears to be so low that the *heat evolved* in them by conversion of mechanical force, in laminating or wire-drawing is sufficient to keep them annealed, *i. e.*, they *cannot be hardened* by such processes. It is this curious fact of molecular physics which affords the explanation of the circumstance well known to those engaged in the trades of rolling sheet lead, or "drawing" lead pipes by the older methods, namely, that the rolling or drawing can be accomplished by a *less total expenditure of power* if performed fast than much more slowly. That is to say, the power demanded is a minimum when the pressure is sufficiently sharp to evolve the heat of annealing in the lead. Upon a like condition (with others not here in question) depends the curious process of forcing up in pure tin the patent collapsible vessels of Rand now so extensively in use for receptacles of oil colors, perfumes, &c.

Baudrimont, a French chemist and physician, has published some most important researches (so far as they go) on annealing temperatures, which may be found in *Ann. de Chim. et Phys.*, tom. ix.; but as respects the *precise* temperature at which annealing takes place, he has only shown, that within certain not very wide limits annealing may be produced if the temperature be long continued; but that there is one point at the highest end of the scale at which annealing takes place instantaneously. To ascertain this point rigidly for all our more important metals would be most desirable, and we would offer to the physical experimentalist some hints as to a method by which probably the investigation might be advantageously pursued.

It has been proved by Magnus (*Ann. de Chim. et Phys.*, tom. xxxiv. 3 *ser.*) and verified by others, that no thermo-electric current can be produced by the heating of any part of a metallic wire, the whole length of which is in the same molecular condition, and its whole surface in the same state, *i. e.*, all polished and free from oxide, &c.

Magnus further ascertained that when one portion of the length of wire was *hard* as it came from the draw plate, and another portion of it had been previously *annealed*, that then, when heat was applied at the point of junction of these respective portions, a thermo-electric current was produced, and gave large deflections with the galvanome-

ter; and that the production of the current was due to a difference in molecular arrangement in the hard and in the annealed portions, and not merely to a difference in their conductivity of *heat.* This he ascertained by showing that annealed and unannealed wire were in this respect the same.

If, then, we arrange a metallic wire or bar, having segments as above, one portion hard, the other annealed, so that it shall pass through a gas flame or furnace, or metallic bath, or other means of heating at the juncture of the segments up to known temperatures, we should expect to find the deflections of the galvanometer increase steadily as the temperature of the bar or wire rises until the moment when such a heat is applied that annealing takes place in the *un*annealed segment of the wire. At this moment the thermo-electric current ceasing altogether, the needle will retrograde to zero, or to its original point, before heat was applied. This occurrence will signal the accomplishment of the molecular change, and the temperature at the moment may be read off from the pyrometric instrument employed and placed in the flame or furnace. Many precautions, some probable difficulties requiring preliminary experiments to disentangle, will readily occur to the physicien, and with him we must leave the subject now. It would be out of place here for us to enter more fully into a purely experimental subject. We have, we trust however, pointed out to the practical man some at least of the sources of difficulty and uncertainty that appertain to his operations of "shrinking on," and in doing so indicated the road by which, with the help of the man of experimental science, he may extricate himself from them.

At the commencement of this paper we put in words, another class of molecular changes, in virtue of which tyres, axles, cannon, and all things formed of metal are presumed, in course of wear and use, to become deteriorated, weakened, or destroyed, namely, crystallization produced by vibration. We shall reserve the consideration of this, however, to a separate article in a future number.

The subject is one of such great practical importance, it is one so little understood, it appears so ill-digested on the part of even some of our leading practical experimentalists on iron, and engineers, and is withal so frequently the subject-matter of ignorant or half informed remarks in our mechanical journals, and on the part of their correspondents, that we shall best devote to it a separate article.

Artificial Plumbago.

From the London Mining Journal, No. 1377.

For some time past, Dr. Crace-Calvert, F. R. S., has been engaged in experimenting upon the composition of a carboniferous substance existing in grey cast iron, or, to use a more popular definition, in producing plumbago from cast iron. The effect of his experiments has been to arrive at results which throw much light upon the chemical

composition of the substance, proving it to be composed of iron, carbon, nitrogen, and silicium. The substance occupies exactly the same volume as the cast iron from which it is obtained, and is sufficiently soft to be easily penetrated by a blade. The mode of experimenting pursued by Dr. Calvert, consisted in placing cubes, one centimetre in dimension, of Staffordshire cold-blast cast iron in corked bottles, with 80 times their volume of weak solutions (each 1 alkalimeter) of the following acids:—Sulphuric, nitric, hydrochloric, acetic, oxalic, tartaric, and gallic. Besides these, phosphoric, carbonic, oleic acids, tannin, and acid peat water, were also used. After three months of contact, he found that although the external appearance of the cubes was not changed in any of the vessels, still those in contact with the weak sulphuric, hydrochloric, and acetic acid solutions, especially the latter, had become so soft externally, that the blade could penetrate three or four millimetres into the cubes. He, therefore, removed the solutions from the vessels, and replaced them by an equal bulk of each weak acid solution, and continued to do so every month for two years, at the end of which time the cubes in contact with the acetic acid ceased to yield iron to the acid, although they were still of the original size; they had, therefore, become transformed into the carbonaceous substance, or artificial plumbago. The action of the weak acetic acid solution Dr. Calvert found to be complete, that of the hydrochloric and sulphuric solutions nearly so, and that of the nitric much less complete, whilst the other solutions either showed no similar action, or a very slight one.

The action of acetic acid on grey cast iron is most interesting; for instead of ceasing when saturated with oxide of iron, as is the case with other acids, its action is continuous, if the precaution be taken to close the mouth of the vessel with an ordinary cork. Thus he has had cubes of cast iron in contact with the same quantity of acetic acid for two years, and the chemical action still existed when the bottles were examined. This action of acetic acid appears, therefore, to be analogous to that which it has on lead. To examine the chemical composition of the cubes transformed by the action of acetic acid, they were reduced to a fine powder in an agate mortar, and well washed with boiled water slightly acidulated with acetic acid. The powder was then dried at 115° Cent. in a dry atmosphere of carbonic acid or hydrogen, according to the nature of the body to be determined in the mass. The cubes of grey cast iron, which originally weighed 15·324 grams., weighed after the two years treatment only 3·489 grammes, and their specific gravity was reduced from 7·858 to 2·751. From the figures, obtained upon careful analysis, it appears that the largest part of the nitrogen originally existing in the cast iron remains in the graphitoid substance, and only a small portion is transformed into ammonia. He has ascertained by direct experiments that it is silicium and not silica that enters into the composition of the carbonaceous mass. Like silicium, the quantity of carbon found in the carbonaceous compound does not represent the whole of the carbon pre-existing in the cast iron, as carburetted hydrogens are given

off during the slow action of the acetic acid in the iron. Dr. Calvert has found the carbonaceous compound (even after the acetic acid has ceased to act upon it) contains 79·960 per cent. of metallic iron—not oxide of iron. Though in the present state of his researches Dr. Calvert considers it would be premature to attempt to assign any definite composition to this substance, we may state that our inference is that it is a compound of sesquiferride of carbon with a nitride of silicium, and the following table given by him substantiates this view:

	Composition of the original views.	Composition of the carbonaceous substance.
Iron, . . .	95·413	79·960
Carbon, . .	2·900	11·020
Nitrogen, . .	0·790	2·590
Silicium, . .	0·478	6·070
Phosphorus, . .	0·132	0·059
Sulphur, . .	0·179	0·096
Lost, . . .	0·108 = 100·000	0·205 = 100·000

As Dr. Calvert's discovery has been referred to in a manner which would induce the opinion that his researches are nothing more than a repetition of those described in a paper "On Black Lead from Cast Iron," by Dr. J. Macculloch, communicated to the *Edinburgh Philosophical Journal* in 1822, we may take this opportunity of stating that the experiments of the two chemists were not similar, and that the results obtained are directly opposed to each other: Macculloch maintained that plumbago is a distinct metal, and that black lead is its oxide, whilst Calvert proves that plumbago (or rather that which Macculloch calls plumbago) is a compound of iron; being, in fact, a compound of about 91 per cent. of a subcarbide of iron, with about $8\frac{1}{2}$ per cent. of a nitride of silicium, and traces of phosphorus and sulphur. Macculloch added little to that which was previously generally known on the subject; but Calvert has carried out his researches with such care and minuteness that we trust ere long to be enabled to give a final reliable opinion upon the subject. In the paper referred to, Dr. Macculloch describes certain experiments which he had made in consequence of his attention having been drawn to specimens of iron that had lain for years at the bottom of the sea, or had been subject to constant soakage in the porter-backs used at breweries. He notices the fact that certain iron guns, fished up in 1740 off Tobermory, from one of the sunken vessels of the Spanish Armada, had become so soft that they could be easily scraped, and that, wherever scraped, the surface of the metal grew too hot to be touched with the hand. A similar phenomenon was observed in some of the iron fittings that had been long exposed to the weak acid present in porter; the metal, moreover, had all the appearance of plumbago, and was not reduced in bulk. The Doctor tested his conclusions by experiments in the laboratory, and found that he could produce plumbago and black lead at pleasure, without any diminution in bulk of the pieces of iron ex-

perimented on; and that the converted metal always became hot if scraped, while any moisture remained, as had been remarked of the long-submerged cannon. In describing his experiments on the soaking of pieces of iron, he mentions that, to procure the black lead in perfection, the acid should be very weak, and the operation is then necessarily tedious. Acetous acid appears to be the best, and it is by this that it is produced in porter-backs, in the waste-pipes of breweries, and in calico-printing houses, where sour paste is used. If the experiment be perfect, the black lead becomes hot on exposure to air, smoking while there is any moisture to be evaporated, particularly when the surfaces are scraped off in succession, so as to give access to the air. Macculloch would thus appear to have proceeded little further than the point at which Calvert commences; for, if we assume the contrary to be the case, we could only come to the conclusion that to express the opinion, as the result of his researches, that the carbonaceous substance found in cast iron was a distinct metal, Macculloch must have been a very clumsy manipulator, and a chemist upon whom no reliance could be placed.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, March 20, 1862.

John Agnew, Vice President, in the chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Chemical Society, the Zoological Society, and the Institute of Actuaries, London; la Société d'Encouragement pour l'Industrie Nationale, Paris, France; the Natural History Society of Montreal, Canada; the Bureau of Topographical Engineers, Hon. Willam D. Kelly, U. S. Congress, and Frederick Emmerick, Esq., Washington City, D. C.; Geo. R. Smith, Esq., Penna. Senate, and Rev. W. R. De Witt, State Librarian, Harrisburg, Penna.; the American Philosophical Society, the Pennsylvania Institution for the Instruction of the Blind, the Schuylkill Navigation Company, Prof. John F. Frazer, and William W. Hubbell, Esq., Philadelphia.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer's statement of the receipts and payments for the month of February was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (2) were proposed, and the candidates proposed at the last meeting (2) were duly elected.

The Actuary reported that the following Standing Committees have

organized by electing their Chairman, and appointing the time for holding their Stated Meetings, viz:

Committee.	*Chairman.*	*Time of Meeting.*
On Library,	James H Cresson,	1st Tuesday evening.
" Exhibitions,	John E. Addicks,	1st Thursday "
" Models,	James Agnew,	2d Monday "
" Meetings,	Washington Jones,	Monday " previous to 3d Thursday.

Mr. Howson exhibited Mr. Gratz's patent Street Annunciator and Panoramic Advertiser, which consists of a box containing a number of rollers and bands; on the latter are printed the addresses of business houses and names of cross streets, if used on street cars, or of the stations, when placed on a railway car. It is operated by either the conductor or brakesman, who, on pulling a lever, rings a bell, and at the same time exposes to view the name of the street or station at which the car has arrived, together with the advertisement of any business house near the crossing or station.

The instrument is simple in its construction, and performs the duties intended with precision. It attracted much attention.

Mr. H. also exhibited a specimen of Mr. T. C. Andrews' Tobacco Pipe, in the bowl of which is placed a lining of porous clay, with a perforated bottom, to be withdrawn when it requires cleaning. The main object of the pipe, and one which is fully attained, is to prevent the nicotine from passing up the stem to the mouth of the smoker, the smoke being consequently milder, and free from the noxious ingredients contained in that drawn from ordinary pipes. Much of the nicotine is also absorbed by the porous clay lining, which may be cleaned by placing it on the coals of a fire, and burning out the matter absorbed.

The patent Axle Splice of Mr. J. E. Balderston was also exhibited. It consists of a block of wood or metal, with a journal at one end for receiving the wheel of a gun carriage or vehicle. If the axle breaks, this splice is secured, by clamps which are attached to the splice, to the broken part, so that an available journal is always presented, however near to the wheel the axle may break.

Mr. Howson also directed the attention of the members to specimens of metal, illustrating the manufacture of Cartridges in the different stages, as made by the very complete automatic machinery of Mr. C. Sharps. Also, a specimen of a new French Cartridge, on which Mr. Sharps has recently made an improvement.

Mr. Nystrom detailed some experiments made by him in repeating Fire Arms, where the barrel was filled with cartridges, to be exploded in succession by fuses running through the balls. He stated that he had been but partially successful.

One of the members remarked that a Mr. Chalmers, of West Middletown, Penna., had patented a gun in 1813, on the same principle, which operated successfully.

Mr. Thomas Shaw, of this city, exhibited a Revolver, illustrating an

improved mode of half-cocking self-cocking pistols. The effect is accomplished by the insertion of a single piece of steel, uniting and combining with the pawl of the hammer in such a manner as to effectually support the hammer away from the cap when not in use; and also to allow it to be perfectly free when firing, an object which heretofore has been rather difficult to accomplish. This arrangement was patented by Mr. Shaw Dec. 24, 1861.

Mr. A. L. Fleury presented some specimens of Iron and Steel, and remarked—

I have been engaged in various experiments on iron and steel, at Danville, Montour County, in order to test several of my improvements on a larger scale. The proprietors of the Pennsylvania Iron Works kindly gave me such facilities as their establishment afforded, and aided by my friend, Mr. Adams, I succeeded in obtaining some valuable results.

Abandoning the expensive batteries and costly induction apparatus, I have now adopted the broken current of a powerful magneto-electric machine, aided by such nitrogenous substances or gases as will aid in carrying off the impurities. After careful comparison with others, I have found these machines (now manufactured by Messrs. Collier & Co. in Binghampton, N. Y.) to be the best adapted to my purposes, because they are the least complicated and cheapest machines made in this country, and require no scientific knowledge and care; any workman can start the belt and stop it when required.

The samples of steel which I now submit for inspection, are made by my process from so-called cold short iron, such as is made from sileceous block ore. This steel is so hard that it will cut into chilled iron, and can be made on a large scale at from 6 to 8 cents per pound. The two samples of cast iron, the one treated in the mould with a current of electricity (broken, as before mentioned), the other cast at the same time and in the same sand, show plainly in their different grain that electricity has the property of changing the nature of the iron, rendering it stronger and more compact.

I have made arrangements with some parties near the City of Philadelphia, for the erection of model works, where can be followed up, practically as well as theoretically, all the various improvements made in the manufacture of iron and steel, and shall be happy to give ocular demonstration of the progress made in this department.

I regret that on account of the weight (about 900 lbs.), and the steam power required for its motion, I am prevented from exhibiting to the members the magneto-electric machine, which I have brought with me from Binghampton. This machine, furnishing a quantitive current equal to one produced by 120 Smee's batteries 4×6, is intended for electro-plating, and will be practically tested by Mr. J. O. Mead, of this city.

Another machine, still larger, and weighing nearly two tons, with 32 magnets, (similar to the one presented for your inspection,) will be finished and sent to me by Messrs. Collier & Co. in about two weeks, when the electric light will be tested in various places on Chestnut

street. Details of all the arrangements will be presented at the next meeting.

Mr. B. H. Bartol exhibited to the meeting several diagrams of the iron-clad steamer *Monitor*, a section of the vessel building at Mystic, Conn., and a model of the one now being built by Merrick & Sons, of this city.

He stated that, while the credit of designing and constructing the *Monitor* belonged to Capt. Ericsson, it was but just to say that the plan of a revolving turret was not his. In fact, Capt. E. had himself, in a recent letter to the editor of the New York *Times*, specially disclaimed being the originator of it, but claiming the peculiar details of the vessel as his. The recent trial of the *Monitor* with the *Merrimac*, while it proved the former's ability to resist the shot of the latter, and in so far was a success, yet her ability to attack and capture has yet to be proved.

A perfectly successful iron-plated war steamer must not be simply a vessel for harbor defence; she must with certainty be able to go along our coast unaided, and in moderately rough weather; and her accommodations must not be a dungeon, requiring artificial light and ventilation. Comfort in time of peace, security in war, and a fair speed, are the essential elements of a war vessel.

The three vessels now building by the Navy Department, were authorized by a law of Congress passed last August, appropriating $1,500,000 for iron-clad vessels. Plans and proposals were advertised for, and a board consisting of Commodores Smith and Paulding, and Capts. Davis and Dahlgren, appointed by the Secretary of the Navy to examine plans and report. This board recommended the three vessels that have been mentioned, of which the *Monitor* is the first. The Mystic vessel will probably be out in May. She is a wooden vessel, plated with two thicknesses of bars, running longitudinally, secured to the wood by through bolts with nuts on the inside. These plates lap on each other in such a way that the head of the bolt is protected on the outside from shot. Her guns are placed on her deck, and above it is a covering of moderately thick sheet iron, which cannot be shot proof, but will no doubt resist musket or rifle balls.

The vessel building in this city by Merrick & Sons, is of timber, plated with iron. She is 240 feet long on deck, 58½ feet beam, and 25 feet hold; 3500 tons; greatest draft of water, 15 feet. She has a berth, gun, and spar deck. She is plated with 4½ inch iron, her whole length for 4 feet below and 3 feet above load line. From that point to spar deck, she is plated 170 feet amidships, and has iron-plated bulkheads across ship at the termination of the side plating. Her spar deck consists of 3 ins. of wood and 1 in. of iron; thus, a clear space on the gun deck, 170 feet long by 54 feet wide, is impervious to shot, unless one enters at the porthole. The battery of this vessel will consist of sixteen 9-inch guns, eight on a side, and a couple of light rifle guns at bow and stern on her spar deck, for chasing and bringing to distant vessels, while her large guns are for engaging war

vessels or land batteries. It is believed that her powers of resistance will enable her to go alongside of any vessel or fort with impunity, while from her large size, she can carry a sufficient force to capture the vessel she may disable. Her speed is to be 9½ knots per hour; at which, with her iron prow in front, she would sink any vessel with which she might come in contact. She is to have three masts, and to be barque rigged; her spars so arranged that, when in action, they all come down to the spar deck. Her machinery consists of two horizontal condensing engines, with cylinders 50 ins. diam. × 30 ins. stroke, to make 85 revolutions turning a 13 ft. propeller. Four horizontal tubular boilers capable of developing 1600 horse power. Coal bunks for ten days steaming. From which it will be seen that this vessel is a cruising ship that may be sent under steam or sail to any part of the world, requiring neither artificial light or ventilation; while those vessels which are purely floating batteries, will rust out at anchor in times of peace.

The construction of iron-clad vessels will make an entire change in naval warfare; and, while it is positive that our reliance for safety is to be in vessels of this class, yet at the same time we should proceed with caution, and not rush headlong into the construction of a large number of vessels, before any one plan has been fully tested. At the present crisis, we should build about a dozen vessels of from 10 to 15 feet draft of water, each of which should have fair speed, and carry in front below the water line an iron prow, for penetrating any vessel with which they may come in contact.

[NOTE.—Revolving turrets or towers, similar to that on the *Monitor*, were patented by Capt. C. P. Coles, of the English Navy, Mar. 30th, 1859, and experimentally applied to the steamer *Trusty*, in August, 1860.]

Mr. B. also exhibited to the meeting a model of a plan for closing ports (when the gun was run in), designed by Chief Engineer W. W. Wood, of the U. S. Navy, and remarked that it was very desirable to have some convenient and secure way of rendering ports ball-proof; but it was exceedingly difficult to devise a plan without having the doors exceedingly heavy, and consequently unwieldy.

METEOROLOGY.

For the Journal of the Franklin Institute.

The Meteorology of Philadelphia. By JAMES A. KIRKPATRICK, A.M.

FEBRUARY.—The temperature of February, 1862, was 7½ degrees below that of the same month of 1861, and about 1½° below the average temperature of the month for eleven years.

The warmest day of the month was the 13th, of which the mean temperature was 42·2°. The maximum for the month (52°) was reached on the same day.

The coldest day was the 10th, with a mean temperature of 22·8°. The minimum (16°) was reached on the same day.

The range of temperature for the month was 36°.

The temperature was below the freezing point on 23 days of the month, though it rose above that point in the course of every day except six, namely, the 3d, 4th, 10th, 21st, 25th, and 28th.

The greatest change of temperature in the course of one day was 22°, on the 12th day of the month; the least was 5°, on the 1st. The average daily oscillation of temperature for the month (10·89°) was 2½° below the average oscillation for the month of February, and was less than occurred in that month since the year 1855, when it was 10·2°.

The greatest mean daily range of temperature was 13·2°, and occurred between the 14th and 15th days of the month; the least was 1°, and occurred between the last day of January and the first of February. The average daily range for the month (5·55°) still continues below the average range. It was nearly 3½° below that for February, 1861, and nearly 2° below the average for eleven years. It was the smallest mean daily range observed in any February during the eleven years of observation. The nearest approach to it was 5·8°, in February, 1855.

The pressure of the atmosphere was greatest on the 16th of the month, when the barometric height corrected for temperature was 30·322 inches. The greatest mean pressure for a day was 30·253 inches, on the 16th. The pressure was least (29·216 ins.) on the afternoon of the 24th. The least mean pressure for a day was 29·454 inches on the 24th. The average pressure for the month (29·917 ins.) was a little less than that for February, 1861, but a little more than the mean pressure for eleven years. The exact difference will be seen in the following table of comparisons.

The greatest mean daily range of atmospheric pressure was 0·717 of an inch, and occurred between the 24th and 25th days of the month; the least was 0·028 of an inch, between the 22d and 23d. The average mean daily range for the month (0·225 in.) was very near the general average for the month of February for eleven years.

The force of vapor was less than usual, at 2 and 9 P. M.; though it was very near the average at 7 A. M. It was greatest (0·267 in.) on the morning of the 24th, and least (0·060 in.) on the morning of the next day, the 25th. The average for the month was sixteen-hundredths of an inch below the general average.

The dew-point following the force of vapor was highest (42°) on the morning of the 24th, and lowest (7·3°) on the 25th. It was about 1° below the general average for February.

The relative humidity was greatest (100 per cent.,) during a fog on the morning of the 24th, and least (44 per cent.) on the afternoon of the 28th. The average humidity for the month was nearly 10 per cent. greater than for February, 1861, and a little over 1 per cent. greater than the average for eleven years.

Rain or snow fell on fifteen days of the month, to the aggregate

depth of 4·277 inches. The number of rainy days was greater than ever before observed in the month of February, the nearest approach to it being 14 days in February, 1859. The amount of rain and melted snow that fell, was an inch and a half more than the average amount for eleven years, and was more than fell during the month in any year, since 1853, when 4·44 inches fell.

Snow fell on eight days of the month, to the aggregate depth of about two feet, but as it was generally soon followed by rain, it remained but a short time on the ground.

There was but one day of the month, the 5th, entirely clear or free from clouds at the hours of observation, and the sky was completely covered with clouds at those hours on nine days. The average amount of the sky covered with clouds during the month of February, 1862, was about 70 per cent.; during February, 1861, it was 58 per cent., and the average amount for eleven years is but 56 per cent. of the hemisphere.

A Comparison of some of the Meteorological Phenomena of FEBRUARY, 1862, *with those of* FEBRUARY, 1861, *and of the same month for* ELEVEN *years, at Philadelphia, Pa.* Latitude 39° 57½′ N.; longitude 75° 10½′ W. from Greenwich.

	Feb. 1862.	Feb. 1861.	Feb. 11 years.
Thermometer.—Highest,	52°	68·5°	70 0°
" Lowest,	16	— 1·0	— 1·0
" Mean daily oscillation,	10·89	17·27	13·40
" Mean daily range,	5·55	8 90	7·29
" Means at 7 A. M.,	28·36	33·86	29·14
" " 2 P. M.,	36·00	45·55	38 44
" " 9 P. M.,	31·64	39·14	33 38
" " for the month,	32·00	39·52	33·65
Barometer.—Highest,	30·322 in.	30·485 in.	30·638 in.
" Lowest,	29·216	29·308	29·065
" Mean daily range,	·225	·264	·221
" Means at 7 A. M.,	29·939	29·954	29·921
" " 2 P. M.,	29·891	29·912	29 873
" " 9 P. M.,	29·922	29·951	29 903
" " for the month,	29 917	29 939	29·899
Force of Vapor.—Means at 7 A. M.,	·130 in.	·158 in.	·139 in.
" " " 2 P. M.,	·143	·169	·164
" " " 9 P. M.,	·142	·186	·160
" " " for the month,	·138	·171	·154
Relative Humidity.—Means at 7 A.M.,	80·4 per ct.	75 0 per ct.	79·6 per ct.
" " " 2 P.M.,	66·6	52·5	64·7
" " " 9 P.M.,	77·9	69·7	76·8
" " "for the month,	75.0	65·7	73·7
Rain and melted snow, amount	4·277 in.	2·124 in.	2·815 in.
No. of days on which rain or snow fell,	15·	9·	10·2
Prevailing winds—Times in 1000-ths,	S.45°0′w.·208	S. 77° 6′w ·354	N70°26′ w ·292

WINTER.—The Winter of 1861–62, was less than half a degree warmer than the average Winter temperature for the last eleven years.